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STEADY STATE RIGOROUS DISTILLATION COLUMN SOLUTIONS

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE IN CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Steady State Rigorous Distillation Column Solutions" submitted by R.I. Tatuch in partial fulfilment of the requirements for the degree of Master of Science in Chemical Engineering.

Abstract

Recent publications have claimed reasonable success with the Chao-Seader correlation in predicting K-ratio data for paraffins, olefins, naphthenes, aromatics and, to a limited extent for dissolved non-hydrocarbon gaseous components, such as carbon dioxide and hydrogen sulfide, in multicomponent hydrocarbon mixtures. This correlation, specifically designed for digital computer calculations, takes into account the composition dependency of the individual component K-ratios. It is a very versatile source of data covering a wide range of temperature and pressure.

Two rigorous multicomponent distillation column calculational procedures, the Thiele-Geddes^(63,59) and a modified version of the approach proposed by Bergamini⁽⁶⁾, incorporating the Chao-Seader correlation, were programmed. A single feed two product distillation column was chosen as the column model for these computer programs. To test these programs and also to compare the combination of the Chao-Seader correlation with a rigorous distillation column calculational procedure to existing rigorous calculations, several literature example problems were calculated. The calculated results, using polynomial and Chao-Seader data, compared well within the twenty percent variation in liquid-vapour and temperature profiles obtained by Stocking, et. al.⁽⁶¹⁾ for example problem 2 using various sources of conventional polynomial data.

For the rigorous design of distillation columns, using these programs, the trial and error approach was taken. As a starting design approximation the Fenske-Underwood-Erbar and Maddox short cut de-

sign combination was programmed. Also, the effects of varying different specified independent variables were investigated for a typical design problem and some of the calculated results were plotted. These plots are presented in Appendix I. If the short cut results did not agree well with the rigorous calculations, the plots were then used as a guide in estimating the desired change in the independent variables for the rigorous Thiele-Geddes or modified Bergamini's calculations to meet the required specifications. To illustrate this design procedure, problems 5, 6 and 7 (a) with specified split on two components and 7 (b) with the split on one component and a specified condenser temperature were solved.

The computer calculation time requirement for problems using the Chao-Seader data was only about three times that required for polynomial data. When considering the work in curvefitting data to polynomials for each problem where a different range of conditions is specified, the additional time requirement for the versatility of a general correlation, such as the Chao-Seader is well worth while.

For the problems considered in this thesis, the Chao-Seader data was found to be sufficiently reliable for design purposes. However, caution must be exercised at other conditions until some feel is obtained for the reliability of this data at the particular temperature, pressure and composition ranges involved.

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(1) Introduction

The design of multistage separation equipment in the petroleum industry becomes complicated when multicomponent systems are considered. Calculations for such systems are often long, repetitive, and tedious. The design of stabilizers is but one such example where the complexity of the rigorous hand calculations has led to a large variety of approximate short cut design methods.

The application of modern high speed digital computers can provide a rapid reliable rigorous solution to the stabilizer design problem. Thus, in a relative short period of time, a number of possible plant schemes and operating conditions can be investigated and the "optimum" design chosen.

In the design of multicomponent multistage separation devices, the vapour-liquid equilibrium data is of foremost importance. It is often not an easy task to convert available equilibrium data to a form which is easily accessible to a computer. This often involves fitting data from a graph or a chart to a suitable polynomial from which the computer can calculate the data as required. In the stabilizer problem the feeds considered may contain a wide range of components from dissolved nonhydrocarbon gases, such as carbon dioxide and hydrogen sulfide, to heavy hypothetical components of the C_{10}^{+} fractions. The equilibrium data for such systems does not only depend on the individual pure component equilibrium data alone, but also on the compositional effect of all the component interactions on the equilibrium relationship.

Of the many existing sources of K-ratios the most widely known are the N.G.S.M.A. K-ratio charts^(41, 43). These charts correlate K-ratios in terms of temperature and pressure; the effect of composition is taken into account by an additional parameter known as the convergence pressure. The range reported is, unfortunately, limited to light hydrocarbons up to decane and only scant data is presented for hydrogen sulfide, carbon dioxide and hydrogen. When this data is curvefitted in a form acceptable to a computer, usually a polynomial in temperature, a serious drawback is encountered in that new data may have to be prepared every time a problem is run at new conditions.

As a result, there exists an increasing need for an accurate and consistent method of calculating composition dependent equilibrium ratios, which is adaptable to computer use. One such approach, for predicting equilibrium and enthalpy data from fundamental properties, was proposed by Chao and Seader⁽⁹⁾. This versatile method can be used to calculate the thermodynamic and equilibrium properties for a wide range of hydrocarbon mixtures including some with non-hydrocarbon gaseous components.

The earliest evaluation of this correlation was performed by Cavett⁽⁸⁾ who employed it in the computation of bubble, dew and flash points for hydrocarbon mixtures. Although this method of K-ratio prediction was found to be time consuming, Cavett suggested the possible use of the Chao-Seader data in rigorous distillation column calculations. Erbar⁽¹⁶⁾ has recently developed the N.G.P.A. flash computer program using this correlation. Also simultaneously, Shelton and Wood⁽⁵⁸⁾ have

independently developed and published a similar program. The latter authors stress the wide range of temperature and pressure over which the Chao-Seader correlation can be applied.

Waterman and Frazier⁽⁶⁵⁾ have recently incorporated this correlation into a rigorous distillation column design computer program based on the Lewis-Matheson approach. An alternative approach to design, which was considered in this thesis, is the trial and error method employing the Thiele-Geddes calculational procedure, as developed by Holland⁽²⁶⁾.

With the present rapid increase in computer calculation speeds, further investigation appears justified into the applicability of a general correlation, such as the Chao-Seader, to rigorous distillation column calculations. It was, therefore, undertaken to develop (a) Thiele-Geddes, and (b) modified Bergamini's method rigorous distillation column computer programs, in which the Chao-Seader correlation was incorporated. Two distinct procedures were chosen to compare the differences of the two main calculational approaches of grouping the equations by column or by stage. The aim of these programs was to determine the feasibility of incorporating a general correlation into a rigorous distillation column computer program. Also, the programs were written to demonstrate how the composition dependent K-ratios can be calculated in combination with a rigorous distillation column calculational procedure. Several stabilizer design problems were then calculated to demonstrate the use of these programs in design.

(2) Literature Survey

(2.1) Rigorous Steady Stage Multicomponent Column Calculations

The digital computer has been the necessary tool for solving the rigorous multicomponent distillation problem. With the development of modern high speed digital computers, the rigorous solution to the distillation column model is now more feasible, providing the data is of sufficient accuracy. The most common computational techniques involve variations of methods proposed by: Lewis and Matheson,^(31,59) Thiele and Geddes,^(63,59) Amundson^(1,2) and Rose, Sweeny and Schrodtt.⁽⁵³⁾ Although some researchers, for example Murdoch⁽⁴⁰⁾ and Underwood,^(64,59) have taken the semianalytical approach to solve the mathematical expressions, by far the vast majority of work has been put into the development of iterative methods, such as those of Thiele and Geddes, Lewis and Matheson, Bergamini and others. These methods select progressively better initial values of the independent variables for each successive trial based on the previous calculation.

There are two general approaches to the solution of the equations representing the distillation column model. These approaches are: the solution of the equations stage by stage for every restriction, as proposed by Greenstadt, et. al.⁽²²⁾ and Bergamini;⁽⁶⁾ and the solution of the equations one restriction at a time for the whole column, such as the Thiele and Geddes and the Lewis and Matheson procedures. Bergamini solves these equations by a simultaneous mass balance, energy balance and temperature correction, stage by stage for the whole column.

On the other hand, the latter approach as taken by Thiele and Geddes calculates the mass balances for the whole column followed by temperature profile correction and energy balances. The order of calculation of (i) mass balances, (ii) temperature corrections and (iii) energy balances, for the solution of the column equations is common to most methods.

In the Lewis-Matheson proposal^(31,59) the feed, reflux and the separation on two components are specified. The distribution of each component between the top and bottom is chosen as the independent variable. This procedure calculates the number of theoretical stages required for a desired separation and is used mainly in the design of new columns. Examples of computer programs of this type are those of Waterman and Frazier⁽⁶⁵⁾ and McIntire⁽³⁸⁾.

A common choice of specifications for the Thiele-Geddes calculational procedure is; feed composition, reflux ratio, distillate rate, feed stage location and the number of theoretical stages. The choice of the number of theoretical stages and the feed stage location as specified variables makes this method useful for the mathematical simulation of operating columns. Holland, et. al.⁽²⁶⁾ have made an extensive study of this calculational procedure as applied to both simple and complex columns. The published computer programs of Hanson⁽²⁴⁾ are also based on an approach similar to the Thiele-Geddes.

The computer programs developed by Amundson^(1,2) are based on the solution of the simultaneous equations, which express the stage and column material and enthalpy balances, by matrix inversion. The variables set are those specified in the Thiele-Geddes method.

Rose, Sweeny and Schrod⁽⁵³⁾ proposed a relaxation method in which they utilize the unsteady state equations to arrive at the steady state solution. When compared to the other existing methods this procedure is slow as far as computer time is concerned. However, it has the particular advantage where complex columns are calculated in that it is not subject to wide fluctuations between iterations. In the case where fluctuations in the conventional methods lead to instabilities in the solution, forcing constraints are necessary to ensure the convergence to the steady state solution.

Friday and Smith⁽²¹⁾ give an excellent discussion on the formulation and solution of the equilibrium stage model for separation problems. They perform a stability analysis to point out the conditions under which the conventional methods, which use the "bubble point" temperature correction method, fail to converge. The "bubble point" method is the term used for the calculation of the corrected temperature profile from the constraint $\sum y_{i,n} = 1$, as used in the Thiele-Geddes and Lewis-Matheson proposals. The effects of damping for convergence forcing, as applied by Holland, are also discussed. As a result of their analysis, Friday and Smith proposed a procedure for obtaining the corrected temperatures from the enthalpy balances. This approach is called the "sum rates" method.

Most of the existing programs are rigorous with respect to the computation of material and energy balances, but fail to take into account the composition dependency of the K-ratio.

Benedict Webb and Rubin⁽⁵⁾ made one of the first proposals to compute composition dependent K-ratios and enthalpy values in a distillation column computer program. For this purpose they used the generalized B.W.R.⁽⁴⁾ equation of state. Cavett⁽⁸⁾ adapted the Chao-Seader correlation together with the Redlich and Kwong⁽⁴⁹⁾, or the Black⁽⁷⁾ equation of state as a method for calculating equilibrium data for hydrocarbon mixtures. Lately, Edmister, Persyn and Erbar⁽¹⁵⁾ and Erbar⁽¹⁶⁾ have modified the Chao-Seader correlation to predict enthalpy data as well. Waterman and Frazier⁽⁶⁵⁾ have recently reported a successful incorporation of the Chao-Seader correlation, together with the Edmister, Persyn and Erbar modification for the enthalpy prediction, in the Lewis-Matheson calculational procedure.

(2.2) Shortcut and Rigorous Approaches to Distillation Column Design

Because the mathematical expressions representing the multi-component distillation problem are nonlinear and can be complicated, a large number of approximate and shortcut design methods have been proposed. Manual calculating methods are best reviewed by textbook authors such as Smith⁽⁵⁹⁾ and Robinson and Gilliland⁽⁵⁰⁾. An extensive review of hand calculating methods was also published by Edmister in a series of papers in the *Petroleum Refiner* from 1947 to 1949. Maddox⁽³⁶⁾ has also published a recent basic and critical review of various shortcut design calculating methods.

The shortcut approach involves the calculation of the minimum number of theoretical stages, at total reflux, by either the Fenske or the Winn method. The minimum reflux is then calculated by one of the following methods developed by Underwood, Bailey and Coates, Erbar and Maddox or Edmister. From the minimum reflux, the operating reflux and the minimum number of theoretical stages, the required number of theoretical stages can be obtained by using either the Gilliland or the Erbar and Maddox correlating charts. For example, Erbar and Maddox⁽¹⁷⁾ have proposed the Winn-Erbar and Maddox (minimum reflux)-Erbar and Maddox, or the Winn-Underwood-Erbar and Maddox shortcut combinations for which they have prepared special correlating charts for design purposes.

In the past, rigorous calculational design methods that used successive approximations in the design of distillation columns were generally based on the calculational procedure of Lewis-Matheson^(59,31). These methods are essentially used for the design of new distillation

columns where the designer has set separation ratios of key component as the design criteria.

Hanson⁽²⁴⁾ and Holland⁽²⁶⁾ have proposed the indirect use of the Thiele-Geddes calculational procedure for the design of distillation columns. Columns with various stage configurations were calculated until a solution, which satisfied the design criteria, was obtained. In this fashion a large variety of specified variable combinations can be handled. Often there are several combinations of variables that will satisfy the set specifications. These can be investigated and the most advantageous combination of the independent variables can then be chosen.

Srygley and Holland⁽⁶⁰⁾ have proposed the use of the multi-variable sequential search technique⁽⁶⁶⁾ with the Thiele-Geddes calculational procedure to calculate an optimum number of ideal stripping and rectifying stages for a set of specifications. This approach may be quite useful for simple columns or for a rapid semiempirical approach where the computer time per calculation is not large. However, for more complicated columns, a larger return of information for the computer time used can usually be obtained from the trial and error approach.

(2.3) K-ratio and Enthalpy Data

The accepted method of representing vapour-liquid equilibrium data for hydrocarbons has been in terms of K-ratios. The equilibrium K-ratio for component "i" is defined as the ratio of its concentration in the vapour phase " y_i " to its concentration in the liquid phase " x_i "

$$K_i = y_i / x_i \quad (2.3-1)$$

The simplest composition independent K-ratio relationship follows from the assumption of Raoult's law for the liquid phase and Dalton's law for the vapour phase. On the assumption of ideal solution in both the vapour and liquid phases, composition independent K-ratios such as those proposed by Lewis and Kay⁽³⁰⁾ and Souders, Selheimer and Brown⁽⁵⁵⁾ can be calculated for a multicomponent system. Of the many such charts and K-ratio correlations proposed, some of the most commonly mentioned are those of Scheibel and Jenney⁽⁵⁶⁾, Maxwell⁽³⁷⁾ and Deprister⁽¹¹⁾. They account for the temperature and pressure dependency of the K-ratios but neglect the composition effect.

Benedict, Webb and Rubin⁽⁵⁾ were one of the first to develop composition dependent K-ratios using the B.W.R. equation of state⁽⁴⁾. They also devised a graphical method which is commonly referred to as the "Kellog Charts". These K-ratios were later correlated in terms of reduced properties by Edmister and Ruby⁽¹⁴⁾.

The use of a third parameter, called convergence pressure, to correlate the effect of composition on the K-ratios in multicomponent mixtures has attained wide popularity. Simple nomographical techniques

for predicting K-ratios based on this principle were developed by Hadden⁽²³⁾ and Winn⁽⁶⁸⁾. The N.G.S.M.A. K-ratio charts, which are the most common source of equilibrium data at present, are also based on the convergence pressure principle. Equilibrium data from these charts has been curvefitted to polynomials in temperature and pressure at various values of the convergence pressure for computer applications⁽⁴²⁾.

There has been a recent stress in literature on the development of general correlations, like those of Chao-Seader⁽⁹⁾ and Orye and Prausnitz⁽⁴⁴⁾ which predict composition dependent equilibrium data over a wide range of temperature and pressure. These correlations usually use an equation of state for the gas phase, curvefit for the liquid fugacity coefficients in terms of reduced properties, and calculate the liquid activity coefficients from a simplified Gibbs excess free energy expression. The Chao-Seader correlation, employing the solubility parameter and the theory of regular solutions, is one such approach. It is applied to mixtures where the deviation from ideal solution in the liquid phase arise mainly from the enthalpy of mixing; the excess entropy of mixing is taken as zero. On the basis of this assumption the Chao-Seader⁽⁹⁾ correlation, together with the Redlich and Kwong equation of state was developed as a computer method for predicting K-ratios in hydrocarbon mixtures. Cavett⁽⁸⁾, Shelton and Wood⁽⁵⁸⁾ and Erbar⁽¹⁶⁾ have all reported favourable results with the Chao-Seader correlation, when used in computer programs in the calculation of flash, dew and bubble point compositions.

To solve the multi-stage multicomponent separation model a source of enthalpy data is also necessary.

The enthalpy of a single pure component is a function of both the temperature and pressure. For many common hydrocarbons the enthalpy data is described by enthalpy charts in references such as Maxwell⁽³⁷⁾ and Edmister⁽¹²⁾. With the assumption of ideal solutions, the enthalpy of a mixture can be calculated from the pure component enthalpies. However, complications arise in that extrapolation is necessary where: (a) a component exists in a liquid phase whose critical temperature is below the temperature of the mixture; or (b) in the vapour phase where the vapour pressure of a component is less than the system pressure.

Mixture enthalpies can be obtained on the basis of an equivalent component having some weighted average molecular weight from plots of enthalpy as a function of temperature, pressure and molecular weight as described by Edmister⁽¹²⁾.

Lydersen, et. al.⁽³³⁾ prepared charts where the enthalpy relative to the ideal gas state is plotted as a function of the reduced properties and the critical compressibility factor. These charts were improved and the correlation converted to mathematical expressions by Yen and Alexander⁽⁶⁹⁾.

Partial molar enthalpies relative to the ideal gas enthalpies that include the effect of temperature, pressure and composition have been calculated, for example, by Edmister, et. al.⁽¹⁵⁾, from thermodynamic relationships for the liquid phase. The vapour phase is handled by an equation of state, for example the Redlich and Kwong equation.

(3) Theory

(3.1) Description of the Distillation Column Mathematical Model

The model chosen was a single feed two product distillation column as described in figure I. The equations representing the model for any stage "n" in the rectifying section or "m" in the stripping section may be expressed as follows:

The equilibrium relationship:

$$y_{i,n} = K_{i,n} x_{i,n} \quad (3.1-1)$$

The component material balance around stage "n" (overall balance implied):

$$l_{i,n} + v_{i,n} - l_{i,n-1} - v_{i,n} + l_{i,n} - f_{i,n} = 0 \quad (3.1-2)$$

The energy balance around stage "n":

$$L_n h_n + V_n H_n - L_{n-1} h_{n-1} - V_n + l_n H_n + l_n - F h_f^* - q_n = 0 \quad (3.1-3)$$

The restriction on fractional concentration:

$$\sum_{i=1}^c x_{i,n} = 1.0 \quad \text{or} \quad \sum_{i=1}^c y_{i,n} = 1.0 \quad (3.1-4)$$

In addition, a sufficient number of specifications must be made to define a unique solution to the problem. A systematic approach to the number of variables to be specified is described in detail by Smith⁽⁵⁹⁾. Hanson⁽²⁴⁾ defines a simple "description rule" for any problem as follows: "To completely describe the separation operation, the number of independent variables which must be set must equal the number that can be set by construction or controlled by external means."

An example list of variables, given by Hanson, that must be specified to completely describe a problem is given in table I.

Table (I)

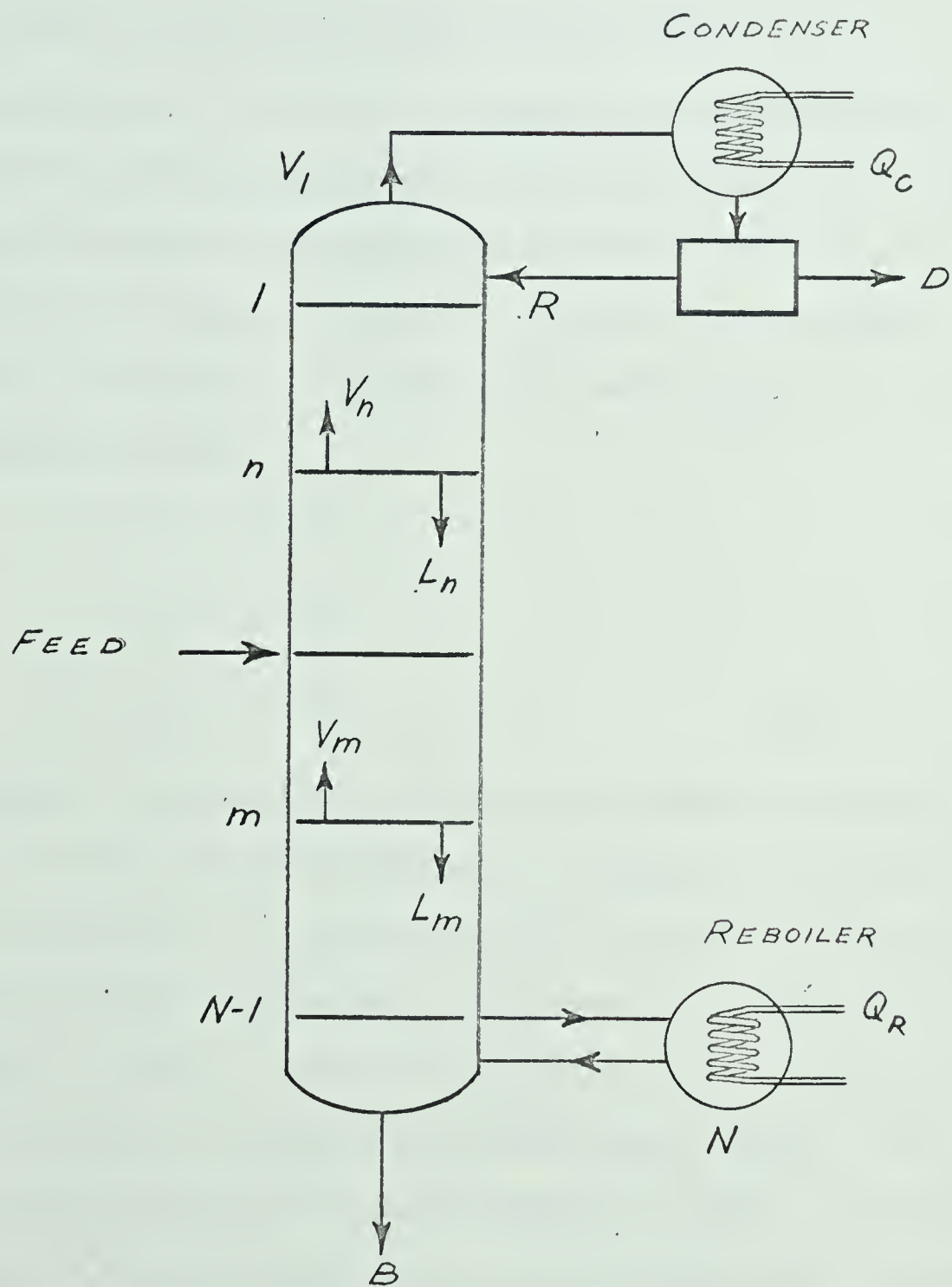
Independent variable	number
Feed Composition (N-components)	N-1
Feed amount	1
Feed enthalpy	1
Column pressure	1
Condenser duty	1
Reflux ratio	1
Number of theoretical enriching stages	1
Number of theoretical stripping stages	1
Reboiler duty	1
	<u>1</u>
	N+7

The set of specifications as listed above would rarely be used. The above list of independent variables can be replaced, in describing the problem, by an equal number of any other independent variables which are most pertinent to the problem of interest. In the case of the model programmed the independent variables are chosen as described in table II.

Table (II)

Independent variable	number
Feed composition (N-components)	N-1
Feed amount (1 lb. mole basis)	1
Feed condition (e.g. bubble point)	1
Column pressure	1
Distillate rate	1
Distillate condition	1
Reflux ratio	1
Total number of theoretical stages	1
Feed stage location	1
	<u>1</u>
	N+7

FIGURE I



DISTILLATION COLUMN

MODEL

Having chosen the model and the specified independent variables that describe the problem, one is faced with the decision of choosing a procedure of solving equations 3.1-1 to 3.1-4. For a distillation separation problem the general procedure is as follows:

Equation 3.1-1 can be used to eliminate either the vapour or the liquid concentrations in equations 3.1-2, 3.1-3 and 3.1-4. The overall material balance can eliminate one flow rate, either L_n or V_n . Assuming that it is required to eliminate $y_{i,n}$ and L_n the remaining equations 3.1-2, 3.1-3 and 3.1-4 respectively can be expressed in the following functional form.

$$C_{i,n}(x_{i,n}, V_n, T_n) = 0 \quad (3.1-5)$$

$$E_n(x_{i,n}, V_n, T_n) = 0 \quad (3.1-6)$$

$$M_n(x_{i,n}, V_n, T_n) = 0 \quad (3.1-7)$$

Equation 3.1-5 is always used to provide numerical values of $x_{i,n}$ or $l_{i,n}$ and these are then substituted into equations 3.1-6 and 3.1-7. Also, equation 3.1-5 is always solved as though it were linear in $x_{i,n}$ and had constant coefficients. Equations 3.1-4 and 3.1-3 are used to generate V_n and T_n . The use of equation 3.1-4 to obtain T_n and 3.1-3 to calculate V_n is called the "bubble point" method. This is the combination employed in the Thiele-Geddes procedure. Alternately the reverse choice is possible and it is called the "sum rates" method. Friday and Smith⁽²¹⁾ have investigated the regions of stability of these two methods and present in detail the advantages of each.

The order of the equations for a distillation problem is generally 3.1-1, 3.1-2, 3.1-4 and 3.1-3. All those permutations in

which equations 3.1-4 or 3.1-3 precede 3.1-1 and 3.1-2 would require the initial assumption of all stage compositions. Also equation 3.1-4 should precede 3.1-3 so that the stream enthalpies can be computed on the normalized compositions.

There are two general approaches to the solution of these equations. One is to solve the equations an individual stage at a time for each restriction. The other is to solve for a restriction at a time for the whole column. Both are used in the solution of the model described in figure I. Bergamini's approach is an example of the former method of "grouping by stages". It requires the additional assumption of the end compositions. The Thiele-Geddes procedure is an example of the latter approach of "grouping by type". An iterative method of solution is most common where successively better values of the independent variables are selected for the next trial until the column converges on the specified criteria.

The degree of complication in the solution of the model equations is to a large extent dependent on the functional form in which the K-ratios are described, $K_{i,n} = f(T_n, P_n, x_{i,n})$. K-ratio data used in equation 3.1-1 are generally available for computer use as curve-fitted functions of temperature at a given pressure. Usually the composition dependency is ignored or taken into account indirectly by such correlating variables as the convergence pressure. The Chao-Seader correlation calculates composition dependent K-ratios. To calculate these directly would require the knowledge of the steady state stage compositions. The K-ratios, therefore, have to be calculated on the basis of the approximate stage concentrations calculated from each

trial. As the column converges to the steady state solution, the stage compositions and temperatures and hence the K-ratios converge to their steady state values.

(3.2) Thiele-Geddes Rigorous Calculation Procedure

The multicomponent distillation column calculational method as proposed by Thiele and Geddes, and as applied by Lyster, Sullivan, Billingsley and Holland⁽³⁵⁾, has been one of the popular approaches to rigorous column calculations. Essentially, the method groups equations 3.1-1, 3.1-2, 3.1-4, and 3.1-3 by "type" and solves for the independent variables $x_{i,n}$, T_n and V_n satisfying one restriction at a time for the whole column by an iterative procedure.

(a) Stage to Stage material balances:

The material balances equations 3.1-2 are solved for the compositions $x_{i,n}$ as follows:

In the rectifying section of the column the equilibrium relationship can be expressed in terms of the top product component molar flow rate " d_i " and the adsorption factor " $A_{i,n}$ ".

$$L_n x_{i,n} = \frac{L_n}{K_{i,n} V_n} V_n y_{i,n}$$

$$l_{i,n} = A_{i,n} v_{i,n}$$

$$\frac{l_{i,n}}{d_i} = \frac{v_{i,n}}{d_i} A_{i,n} \quad (3.2-1)$$

Component "i" material balances around the top of the column, numbering from top to bottom, can then be written as:

$$\frac{v_{i,n}}{d_i} = \frac{l_{i,n-1}}{d_i} + 1 \quad (3.2-2)$$

Substituting equations 3.2-1 in 3.2-2 to obtain the relationship:

$$\frac{l_{i,n}}{d_i} = A_{i,n} \left(\frac{l_{i,n-1}}{d_i} + 1 \right) \quad (3.2.3)$$

The calculations are started by calculating $\frac{l_{i,0}}{d_i}$ from the reflux ratio "R":

For a total condenser
$$\frac{l_{i,0}}{d_i} = R \quad (3.2-4)$$

For a partial condenser
$$\frac{l_{i,0}}{d_i} = \frac{R}{K_{i,0}} \quad (3.2-5)$$

Equation 3.2-3 is then applied to each stage in succession until the ratio $\frac{l_{i,f-1}}{d_i}$ from the stage above the feed stage is obtained. The material balance calculations are then switched to the stripping section.

Similarly to the rectifying section, the stripping section equilibrium relationship for component "i" can be expressed in terms of the stripping factor " $S_{i,m}$ " and the bottoms component molar flow rate " b_i ".

$$V_m y_{i,m} = \frac{K_{i,m} V_m}{L_m} L_m x_{i,m}$$

$$v_{i,m} = S_{i,m} l_{i,m} \quad (3.2-6)$$

Component "i" material balances around the bottom of the column can be written as:

$$\frac{v_{i,m}}{b_i} = \frac{l_{i,m}}{b_i} S_{i,m} \quad (3.2-7)$$

Also similarly to the rectifying section we obtain:

$$\frac{l_{i,m-1}}{b_i} = \frac{l_{i,m}}{b_i} S_{i,m} + 1 \quad (3.2-8)$$

Equation 4.2-8 is then applied to each of the stripping stages, starting at the bottom of the column, until the ratio $\frac{l_{i,f-1}}{b_i}$ is obtained in the liquid entering the feed stage "f".

The normalized liquid compositions are then calculated from the $\frac{l_{i,n}}{d_i}$ and $\frac{l_{i,m}}{b_i}$ ratios and $b_{i_{co}}$ and $d_{i_{co}}$ which are obtained from the mismatch at the feed plate and from the theta convergence method as described in section 3.4.

$$x_{i,n} = \frac{(l_{i,n}/d_i) d_{i_{co}}}{\sum_{i=1}^c (l_{i,n}/d_i) d_{i_{co}}} \quad (3.2-9)$$

$$x_{i,m} = \frac{(l_{i,m}/b_i) b_{i_{co}}}{\sum_{i=1}^c (l_{i,m}/b_i) b_{i_{co}}} \quad (3.2-10)$$

(b) Temperature Profile Correction:

In the Thiele-Geddes approach the temperature corrections are made by the "bubble point" method. This involves the solution for the stage temperature that satisfies the restriction equation 3.1-4, using the normalized liquid stage compositions. The restriction to be satisfied may be written as:

$$\sum_{i=1}^c x_{i,n} K_{i,n} - 1 = 0 \quad (3.2-11)$$

The method used to solve equation 3.2-11 is dependent on the functional form in which $K_{i,n}$ is dependent on T_n , P_n and $x_{i,n}$. For differentiable functions of $K_{i,n}$, which respect to temperature, Newton's method^(29,26) may be used. However, for more complicated relationships such as the Chao-Seader approach a trial and error method as described by equation 3.2-12 may be more applicable.

$$(T_n)_{co} = (T_n)_{ca} \left\{ 1 + \frac{1 - \sum_{i=1}^c y_{i,n}}{5} \right\} \quad (3.2-12)$$

(c) Vapour-Liquid Profile Correction:

New vapour and liquid profiles are calculated from the enthalpy balance relationship as described by equation 3.1-3. The two methods of column enthalpy balances which were investigated for possible use with the Thiele-Geddes approach are derived as follows:

(i) Bottom up Enthalpy Balances

The individual "V's", vapour flow rates, can be expressed by a series of enthalpy balances around the individual stages starting at the bottom of the column as follows:

Balances around the bottom stage "k":

$$(H_k - h_{k-1}) V_k = B (h_{k-1} - h_k) + Q_R \quad (3.2-13)$$

$$V_k = \frac{B(h_{k-1} - h_k) + Q_R}{H_k - h_{k-1}} \quad (3.2-14)$$

Then calculating up the column in the stripping section:

$$L_{m-1} = V_m + B$$

$$L_m = V_{m+1} + B$$

$$L_{m-1} h_{m-1} + V_{m+1} H_{m+1} = L_m h_m + V_m H_m \quad (3.2-15)$$

substituting for L_{m-1} and L_m

$$V_m = \frac{V_{m+1} (H_{m+1} - h_m) + B (h_{m-1} - h_m)}{H_m - h_{m-1}} \quad (3.2-16)$$

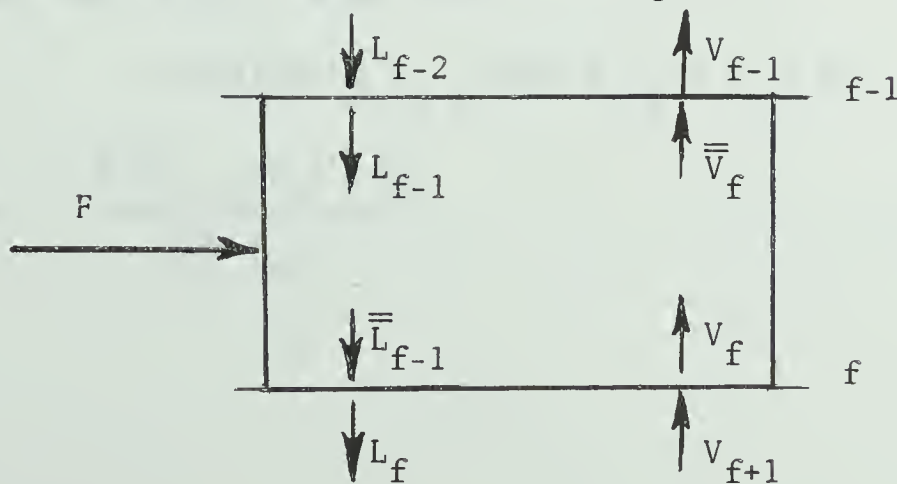
At the feed stage the energy balance is:

$$Fh_f^* + L_{f-1} h_{f-1} + V_{f+1} H_{f+1} = \overline{\overline{V}}_f \overline{\overline{H}}_f + L_f h_f \quad (3.2-17)$$

Substituting $L_{f-1} = \overline{\overline{V}}_f - D$ and $L_f = V_{f+1} + B$

$$\overline{\overline{V}}_f = \frac{V_{f+1} (H_{f+1} - h_f) + Fh_f^* - Dh_{f-1} - Bh_f}{\overline{\overline{H}}_f - h_{f-1}} \quad (3.2-18)$$

where "f" is the feed stage as shown below:



In the rectifying section the energy and mass balances are:

$$L_{n-1} h_{n-1} + V_{n+1} H_{n+1} = V_n H_n + L_n h_n \quad (3.2-19)$$

$$L_n = V_{n+1} - D$$

$$L_{n-1} = V_n - D$$

substituting for L_n and L_{n-1}

$$V_n = \frac{V_{n+1} (H_{n+1} - h_n) - D (h_{n-1} - h_n)}{H_n - h_{n-1}} \quad (3.2-20)$$

(ii) Enthalpy Balances from Both Ends of the Column

In the rectifying section the energy balance around any

tray "n" is:

$$V_n H_n = L_{n-1} h_{n-1} + D h_D + Q_C \quad (3.2-21)$$

substituting for $L_{n-1} = V_n - D$

$$V_n = \frac{D (h_D - h_{n-1}) + Q_C}{H_n - h_{n-1}} \quad (3.2-22)$$

The balances in the stripping section made around the

bottom of the column are:

$$L_{m-1} h_{m-1} + Q_R = V_m H_m + B h_B \quad (3.2-23)$$

eliminating L_{m-1} with $L_{m-1} = V_m + B$

$$V_m = \frac{B (h_{m-1} - h_B) + Q_R}{H_m - h_{m-1}} \quad (3.2-24)$$

(3.3) Modified Bergamini's Computational Procedure

The calculational procedure as applied by Bergamini⁽⁶⁾ for ideal stage multicomponent distillation column calculation differs from that of Thiele-Geddes in that equations 3.1-3, 3.1-2, 3.1-4 and 3.1-3 are grouped by stage. Thus material balances, enthalpy balances and temperature corrections are applied simultaneously in calculating up and down the column.

(a) Material and Enthalpy Balances

In the rectifying section, the material balance for component "i" is:

$$v_{i,n} = d_i + l_{i,n-1} \quad (3.3-1)$$

Overall material balance:

$$L_{n-1} = V_n - D$$

The energy balance for the same stage is:

$$\sum_{i=1}^c H_{i,n} v_{i,n} = \sum_{i=1}^c h_{i,n-1} l_{i,n-1} + Q_C + \sum_{i=1}^c d_i h_{i,D} \quad (3.3-2)$$

Substituting for $v_{i,n}$ and $l_{i,n-1} = L_{n-1} x_{i,n-1}$

$$L_{n-1} = \frac{Q_C + \sum_{i=1}^c (h_{i,D} d_i) - \sum_{i=1}^c (H_{i,n} d_i)}{\sum_{i=1}^c (H_{i,n} x_{i,n-1}) - \sum_{i=1}^c (h_{i,n-1} x_{i,n-1})} \quad (3.3-3)$$

The calculations in the rectifying section are started by calculating " $l_{i,0}$ " from the reflux ratio "R":

$$l_{i,0} = R D x_{i,D}$$

For any stage "n" equation 3.3-1 is applied to obtain the set of $v_{i,n}$. The normalized compositions are then calculated from the component flow rates followed by L_{n-1} from equation 3.3-3.

$$y_{i,n} = \frac{v_{i,n}}{\sum_{i=1}^c v_{i,n}} \quad (3.3-4)$$

$$x_{i,n} = \frac{v_{i,n}/K_{i,n}}{\sum_{i=1}^c v_{i,n}/K_{i,n}} \quad (3.3-5)$$

Equations 3.3-1, 3.3-3, 3.3-4 and 3.3-5 are then applied down the column until $l_{i,f-1}$ is obtained in the overflow from the stage above the feed.

In the stripping section the relationships for stage "m" are;

Material balance on the " i^{th} " component:

$$l_{i,m} = v_{i,m} + b_i \quad (3.3-6)$$

" b_i " is the net molar flow rate of component "i" out of the bottom of the column.

Overall material balance:

$$V_{m+1} = L_m - B$$

Energy Balance:

$$\sum_{i=1}^c (h_{i,m} l_{i,m}) + Q_R = \sum_{i=1}^c (H_{i,m+1} v_{i,m+1}) + \sum_{i=1}^c (b_i h_{i,B}) \quad (3.3-7)$$

substituting for $l_{i,m}$ and $v_{i,m+1} = V_{m+1} y_{i,m+1}$

$$V_{m+1} = \frac{\sum_{i=1}^c (b_i \bar{h}_{i,B}) - \sum_{i=1}^c (\bar{h}_{i,m} b_i) - Q_R}{\sum_{i=1}^c (y_{i,m+1} \bar{h}_{i,m}) - \sum_{i=1}^c (y_{i,m+1} \bar{H}_{i,m+1})} \quad (3.3-8)$$

The normalized vapour and liquid compositions are then calculated from the liquid component molar flow rates.

$$y_{i,m} = \frac{l_{i,m} K_{i,m}}{\sum_{i=1}^c (l_{i,m} K_{i,m})} \quad (3.3-9)$$

$$x_{i,m} = \frac{l_{i,m}}{\sum_{i=1}^c (l_{i,m})} \quad (3.3-10)$$

Equations 3.3-6, 3.3-7, 3.3-8 and 3.3-9 are then applied starting at the bottom stage of the column to the feed stage.

(b) Stage Temperature Correction

A parameter " χ ", the ratio of the dew point to the bubble point, is used to calculate the temperature correction instead of the "bubble point" calculation.

For the rectifying section:

$$\chi_n = \frac{\sum_{i=1}^c (v_{i,n}/K_{i,n})}{\sum_{i=1}^c (v_{i,n})} \quad (3.3-11)$$

For the stripping section:

$$\chi_m = \frac{\sum_{i=1}^c (l_{i,m})}{\sum_{i=1}^c (l_{i,m} K_{i,m})} \quad (3.3-12)$$

$\chi_n = 1$ for the true temperature at the stage. The deviation of " χ " from unity is then an estimate of the difference in T_{ca} from the true stage temperature.

A new set of K-ratios, $(K_{i,n})_{co}$ is then obtained by multiplying the calculated $K_{i,n}$ by χ_n :

$$(K_{i,n})_{co} = K_{i,n} \chi_n \quad (3.3-13)$$

Corresponding to these $(K_{i,n})_{co}$ there exists a temperature vector $T_{i,n}$. To calculate this temperature vector $\ln (K_{i,n})$ is assumed to vary linearly with temperature. A slope $\psi_{i,n}$ is then calculated where:

$$\psi_{i,n} = \frac{\ln (K_{i,n})_{T_n+5} - \ln (K_{i,n})_{T_n}}{5} \quad (3.3-14)$$

From the linear relationship the temperature vector $T_{i,n}$ is:

$$T_{i,n} = T_n + \psi_{i,n} \{ \ln (K_{i,n})_{co} - \ln (K_{i,n}) \} \quad (3.3-15)$$

The corrected temperature is then a weighted mean of the temperature vector $T_{i,n}$.

Rectifying section:

$$T_{n,co} = \frac{\sum_{i=1}^c (T_{i,n} v_{i,n}/K_{i,n})}{\sum_{i=1}^c (v_{i,n}/K_{i,n})} \quad (3.3-16)$$

Stripping section:

$$T_{m,co} = \frac{\sum_{i=1}^c (T_{i,m} l_{i,m} K_{i,m})}{\sum_{i=1}^c (l_{i,m} K_{i,m})} \quad (3.3-17)$$

If, after two corrections, the stage temperature has not converged a forcing technique described by Tedley⁽⁶²⁾ and also by Bergamini is used, where T_{nf} is the tentative value taken for the stage temperature.

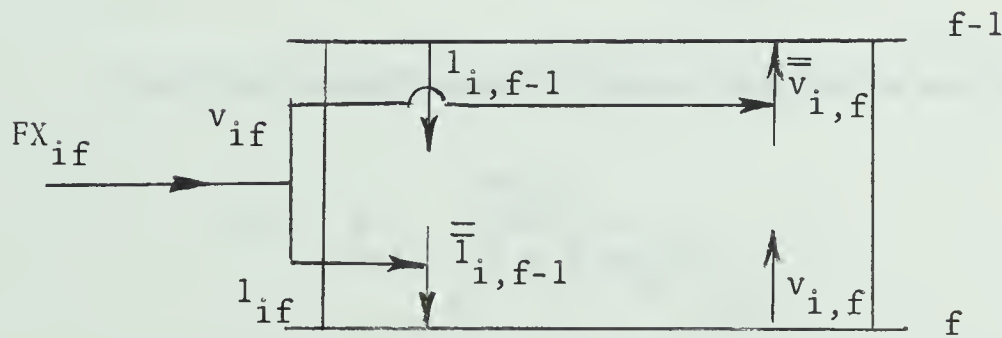
$$T_{nf} = \frac{T_{n2a} T_{n1co} - T_{n1a} T_{n2co}}{T_{n2a} + T_{n1co} - (T_{n1a} + T_{n2co})} \quad (3.3-18)$$

(3.4) Mismatch at the Feed Stage and the Theta Method of Convergence

The mismatch at the feed stage and the theta method of convergence are applied to both the Bergamini and the Thiele-Geddes calculational procedures as developed by Holland⁽²⁶⁾. The general expression for the calculated ratio of bottom product component molar flow rate to the top product component molar flow rate, $(b_i/d_i)_{ca}$ is:

$$\left(\frac{b_i}{d_i}\right)_{ca} = \frac{\frac{l_{i,f-1}}{d_i} + \frac{l_{if}}{FX_{if}}}{\frac{v_{i,f}}{b_i} + \frac{v_{if}}{FX_{if}}}$$

Where "f" is the feed stage as shown below:



The corrected $(b_i/d_i)_{co}$ values are defined as those which give D specified and simultaneously satisfy both the component and material balances. An empirical expression was developed by Holland, et. al. (26,35) relating the $(b_i/d_i)_{ca}$ to the corrected values. Holland, et. al. proposed to use a multiplier " θ " independent of any particular component and defined by:

$$\left(\frac{b_i}{d_i} \right)_{co} = \theta \left(\frac{b_i}{d_i} \right)_{ca} \quad (3.4-2)$$

From the material balance of component "i":

$$FX_{if} = (d_i)_{co} + (b_i)_{co} \quad (3.4-3)$$

and equation 3.4-2:

$$(d_i)_{co} = \frac{FX_{if}}{1 + \theta (b_i/d_i)_{ca}} \quad (3.4-4)$$

For the specified distillate rate to be satisfied:

$$D = \sum_{i=1}^c \left\{ \frac{FX_{if}}{1 + \theta (b_i/d_i)_{ca}} \right\} \quad (3.4-5)$$

Equation 3.4-5 can be solved for θ using numerical search techniques. An objective function $g(\theta)$ is defined as:

$$g(\theta) = D_{spec} - \sum_{i=1}^c \frac{FX_{if}}{1 + \theta (b_i/d_i)_{ca}} \quad (3.4-6)$$

The solving of this objective function for the root θ is commonly carried out by Newton's root finding method^(29,26). This involves evaluating the derivative $g(\theta)'$.

$$g(\theta)' = - \sum_{i=1}^c \frac{FX_{if}}{\{ 1 + \theta (b_i/d_i) \}_{ca}^2} \quad (3.4-7)$$

Starting from an assumed θ_a the next approximation for θ_r is θ_{co} and it is calculated by:

$$\theta_{co} = \theta_a - \frac{g(\theta_a)}{g'(\theta_a)} \quad (3.4-8)$$

To ensure convergence by the Newton's method the first assumed value for θ_a should be $0 \leq \theta_a \leq \theta_r$, where θ_r is the root satisfying equation 3.4-6. Since $\theta_a = 0$ represents one value that always satisfies the inequality the first value of θ_a should be very small or equal to zero.

As the solution for the column converges the root θ_r approaches unity.

(3.5) Fenske-Underwood-Erbar and Maddox Short Cut Design Method

The Fenske⁽¹⁹⁾-Underwood^(64,59)-Erbar and Maddox⁽¹⁷⁾ short cut design combination was used to obtain approximate values of the independent variables; the total number of theoretical stages, the operating reflux ratio and the distillate rate. These specifications were then used as a starting point for the Thiele-Geddes or the modified Bergamini's procedure program to obtain the rigorously calculated design by trial and error.

(a) Fenske's Method for Calculating the Minimum Number of Stages

The equation developed by Fenske⁽¹⁹⁾ relates the separation obtained between two components at total reflux, to the minimum number of equilibrium stages.

For a total condenser the Fenske equation is:

$$\left(\frac{x_i}{x_r} \right)_D = \alpha_{i_{av}}^N \left(\frac{x_i}{x_r} \right)_B \quad (3.5-1)$$

For a partial condenser:

$$\left(\frac{y_i}{y_r} \right)_D = \alpha_{i_{av}}^{N+1} \left(\frac{x_i}{x_r} \right)_B \quad (3.5-2)$$

where α_i is the relative volatility and is defined as:

$$\alpha_i = \frac{K_i}{K_r} \quad (3.5-3)$$

where "r" is the reference component.

The average relative volatility $\alpha_{i_{av}}$ in terms of the two key components is:

$$\alpha_{i_{av}} = \left\{ (\alpha_{1k-hk})_{\text{bottom}} (\alpha_{1k-hk})_{\text{middle}} (\alpha_{1k-hk})_{\text{top}} \right\}^{\frac{1}{3}} \quad (3.5-4)$$

If the splits on two components are specified the minimum number of theoretical stages, at total reflux, and the product distribution are calculated from equations 3.5-1 or 3.5-2. The two components " i_{1k} " and " i_{hk} " are referred to as the light and heavy key components respectively.

(b) Minimum Reflux from the Underwood Equations

The minimum reflux is defined as that reflux rate which, if decreased, an infinitesimal amount would require an infinite number of stages to produce the specified separation between the two key components. In a multicomponent column, that reflux ratio which causes a zone of constant composition to appear is taken as the minimum reflux. If a zone of constant composition appears in one section only, it is assumed to be possible to shift the feed location and hence the loading so that the reflux ratio is further decreased until the zone of constant composition appears in both sections. Thus, the minimum reflux concept assumes the ideal feed stage location.

Underwood^(64,69), on assuming constant molar overflow and constant relative volatilities, developed the following expressions for the minimum reflux.

For the rectifying section:

$$\sum_{i=1}^c \frac{\alpha_i (x_{i,D})}{\alpha_i - \theta} @ R_m = R_m + 1 \quad (3.5-5)$$

For the stripping section:

$$\sum_{i=1}^c \frac{\alpha_i (x_{i,B})}{\alpha_i - \theta} @ R_m = - \frac{V_B}{B} \quad (3.5-6)$$

$$R_m = \frac{V_B + F_{vap.} - D}{D} \quad (3.5-7)$$

The variable theta " θ " is the common root of the stripping section equation 3.5-5 and the rectifying section equation 3.5-6 and satisfies the restriction $\alpha_{lk} \leq \theta \leq \alpha_{hk}$. By combining the equation 3.5-5 and 3.5-6 equation 3.5-8 is obtained, which relates " θ " to the thermal condition and the composition of the feed.

$$\sum_{i=1}^c \frac{\alpha_i x_{if}}{\alpha_i - \theta} = 1 - q \quad (3.5-8)$$

where " q " is defined as:

$$q = \frac{\begin{array}{l} \text{(Heat necessary to raise a mole of feed to} \\ \text{the saturated vapour condition)} \end{array}}{\begin{array}{l} \text{(Heat necessary to raise a mole of saturated} \\ \text{liquid of the same composition} \\ \text{as the feed to the saturated vapour condition)} \end{array}} \quad (3.5-9)$$

Equation 3.5-8 is solved for θ . The θ so obtained together with the top and bottom compositions at minimum reflux can be substituted into equation 3.5-5 or 3.5-6 to obtain the minimum reflux. For practical purposes the top and bottom compositions, obtained from the Fenske equation, at total reflux are assumed to be sufficiently close to those

at minimum reflux and are used in equations 3.5-5 and 3.5-6. The operating reflux "R_o" is then obtained by multiplying the minimum reflux by some factor generally between 1.2 and 1.5.

For example:

$$R_o = 1.3 R_m \quad (3.5-10)$$

(c) Required Number of Theoretical Stages from the Erbar and Maddox Charts

The minimum reflux "R_m", operating reflux "R_o" and the minimum number of theoretical stages obtained from the Fenske equation are then used in the correlation proposed by Erbar and Maddox⁽¹⁷⁾ to obtain the required number of theoretical stages. Erbar and Maddox have developed plots of (L_o/V₁) operating vs (N_m/N) at various (L_o/V₁)_{minimum} for both the Winn-Erbar and Maddox and Winn-Underwood, minimum number of stages and minimum reflux combinations. These charts are based on the bubble point feed condition only. To account for the various feed conditions Erbar, et. al. have developed a correction equation which modifies the operating reflux rate for a feed in the region between the saturated liquid and the saturated vapour.

$$V_{lu} = V_{lk} + \frac{(1 - \frac{D}{F}) (h_f^* F_u - h_f^* F_k)}{(\frac{Q_C}{L_{CT}})_k} \quad (3.5-11)$$

where:

"u"	=	unknown condition
"k"	=	known condition
"L _{CT} "	=	total amount of liquid leaving the condenser
"h _f [*] "	=	total feed enthalpy

The correction is made on the operating reflux only using equation 3.5-11 and the number of stages is read from the charts as before. The assumptions made for equation 3.5-11 are:

(i) The latent head of condensation of the vapour leaving the top tray of the fractionator will not change appreciably with the reflux rate.

(ii) The sensible heat effects in the condensor are negligible when compared to the latent heat effects.

Erbar and Maddox caution that the correcting equation was developed for feeds between the bubble and dew point conditions only and may not be valid outside this range.

(3.6) Chao-Seader K-ratio Correlation

The general Chao-Seader K-ratio can be described as follows:

The nonideal gas and nonideal solution assumption for the gas phase are handled by the vapour fugacity coefficient " ϕ_i ", where " ϕ_i " is defined as:

$$\phi_i = \frac{f_{iv}}{P_i} \quad (3.6-1)$$

The vapour phase is then described by the following equation:

$$f_{iv} = \phi_i y_i P \quad (3.6-2)$$

For the liquid phase the assumption of nonideal solution is made:

$$f_{il} = x_i \gamma_i f_{il}^\circ \quad (3.6-3)$$

At equilibrium:

$$f_{iv} = f_{il}$$

hence:
$$\phi_i y_i P = x_i \gamma_i f_{il}^\circ$$

The equilibrium K-ratio is therefore defined by:

$$K_i = \frac{\gamma_i f_{il}^\circ}{\phi_i P} \quad (3.6-4)$$

As the general expressions for ϕ_i , γ_i and f_{il}°/P are described by approximating functions, the accuracy of the K-ratio as defined in equation 3.6-4 is therefore dependent on the simplifying assumptions and the accuracies of the various curvefits involved.

In the Chao-Seader correlation the expression for ϕ_i is obtained

from the Redlich and Kwong equation of state. The generalized liquid fugacity " f_{i1}^o/P " is curvefitted in terms of reduced properties T_R , P_R and ω_i . The liquid activity coefficient " γ_i " is calculated from the Gibbs excess free energy expression where ΔS_i^m is assumed to be zero.

$$\Delta F_i^m = \Delta H_i^m - T \Delta S_i^m \quad (3.6-5)$$

The assumption of $\Delta S_i^m = 0$ is the main assumption of the Chao-Seader correlation and the correlation is therefore limited to mixture of components which satisfy the "regular" solution theory.

(a) Calculation of the liquid fugacity coefficients

The theoretical relationship used to calculate the value of the liquid-fugacity coefficient, $f_{i1}^o/P = v_i^o$, arose from the studies of the principle of corresponding states. Statistical theory shows that a group of substances will conform to the principle of corresponding states only if their intermolecular properties are identical, except for the intermolecular distances and energy scale factors, characteristic of each substance⁽³²⁾. The heavy rare gases Ar, Kr and Xe, "simple" fluids, satisfy these criteria and conform to the corresponding states behaviour.

Pitzer, et. al.^(47,45) extended the theory of corresponding states involving a third parameter " ω ", called the acentric factor. Any property of a fluid in reduced dimensionless form is then assumed to be given as a function of three variables (P_R , T_R and ω).

$$Z_i = f(P_R, T_R, \omega_i)$$

$$Z_i^{\circ} = Z_i^{(0)}(P_R, T_R) + \omega_i Z_i^{(1)}(P_R, T_R) \quad (3.6-6)$$

$$Z_i^{(0)} = \text{expression for "simple fluid"}$$

$$Z_i^{(1)} = \text{deviation from a "simple" fluid}$$

Edmister⁽¹⁴⁾ showed that the third parameter, the acentric factor, might be calculated from the component physical properties; the critical temperature, critical pressure and the normal boiling point.

The liquid fugacity coefficient " v_i° " is then calculated in an analogous manner with the use of the acentric factor as the third parameter:

$$\log v_i^{\circ} = \log v_i^{(0)} + \omega_i \log v_i^{(1)} \quad (3.6-7)$$

$v_i^{(0)}$ gives the liquid fugacity coefficient of a "simple" fluid. $v_i^{(1)}$ accounts for the departure of properties from that of a "simple" fluid.

Chao and Seader⁽⁹⁾, using experimental data, have curvefitted the expressions for $v_i^{(0)}$, and $v_i^{(1)}$ with approximating functions:

$$\begin{aligned} \log v_i^{(0)} = & A_1 + A_2/T_R + A_3 T_R + A_4 T_R^2 + A_5 T_R^3 + (A_6 + A_7 T_R + A_8 T_R^2) P_R \\ & + (A_9 + A_{10} T_R) P_R^2 - \log P_R \end{aligned} \quad (3.5-8)$$

$$\log v_i^{(1)} = A_{11} + A_{12} T_R + A_{13}/T_R + A_{14} T_R^3 + A_{15} (P_R - 0.6) \quad (3.6-9)$$

(b) Calculation of the Liquid Activity Coefficient

The composition effect in the liquid phase is calculated from the Hildebrand Scatchard⁽⁵⁶⁾ equation for "regular" solutions. A "regular" solution is defined as "One involving no entropy change when a small amount of one of its components is transferred to it from an ideal solution as the same composition, the total volume remaining unchanged". The non ideality of a "regular" solution is, therefore, entirely due to its heat of mixing. While no solutions are actually "regular", the properties of solutions of nonpolar fluids such as hydrocarbons are approximated by the "regular" solution assumption.

It was shown by Hildebrand and Scott⁽²⁵⁾ that the activity coefficient of component "i" in a "regular" liquid solution containing "n" components is given by:

$$\ln \gamma_i = \frac{V_i^*}{R^*T} (\delta_i - \bar{\delta}_m) \quad (3.6-10)$$

$$\delta_i = \left(\frac{\Delta E_i}{V_i^*} \right)^{1/2} \approx \left[\frac{\lambda_i - PV_i^*}{V_i^*} \right]^{1/2}$$

$$\bar{\delta}_m = \sum_{i=1}^c \frac{\delta_i x_i V_i^*}{x_i V_i^*}$$

The parameters " δ_i " called solubility parameters are calculated from^(56,25) the heat of vaporization for the heavier hydrocarbons and from gas solubility data for light hydrocarbons and gases. Recently, Lyckman, Eckert and Prausnitz⁽³³⁾ published correlations for the solubility parameter and the molar volume in terms of reduced properties and the acentric factor. These correlations also include slightly polar compounds.

A detailed discussion of equations 3.6-10 appears in the papers published by Prausnitz, Edmister and Chao⁽⁴⁸⁾, Edmister⁽¹²⁾ and Chao and Seader⁽⁹⁾. In the earlier article of Prausnitz, Edmister and Chao, both the solubility parameter and the component molar volume " V_i^* " are considered to be functions of temperature. Prausnitz, Edmister and Chao have decided that because the solubility parameter involved a difference which was relatively independent of temperature the solubility parameter could be considered as constant at their 25°C values. Chao and Seader, in their application of the correlation, also do not allow either the solubility parameter or the molar volume to vary with temperature and assume them to be constant at their 25°C values.

(c) Calculation of the Vapour Fugacity Coefficient " ϕ_i "

The fugacity coefficients in the vapour phase are calculated from the derived expression from the Redlich and Kwong⁽⁴⁹⁾ equation of state.

$$Z = \frac{1}{1-h} - \frac{A^2}{B} \frac{h}{1+h} \quad (3.6-11)$$

$$h = \frac{BP}{Z}$$

This equation of state requires two constants for each component " A_i " and " B_i ", which are directly related to the critical and physical properties of the components.

$$A_i = \left[\frac{a}{R^2 T^{2.5}} \right]^{\frac{1}{2}} = \left\{ \frac{0.4278}{P_C T_R^{2.5}} \right\}^{1/2} \quad (3.6-12)$$

$$B_i = \frac{0.0867}{T_R P_C} \quad (3.6-13)$$

$$A = \sum_{i=1}^c y_i A_i, \quad B = \sum_{i=1}^c y_i B_i$$

The fugacity coefficients of the components in the gaseous mixture, are then obtained from the expression derived from the Redlich and Kwong equation of state⁽⁴⁹⁾.

$$\ln \phi_i = (Z-1) \frac{B_i}{B} - \ln (Z-BP) - \frac{A^2}{B} \left\{ \frac{2A_i}{A} - \frac{B_i}{B} \right\} \ln \left(1 + \frac{BP}{Z} \right) \quad (3.6-14)$$

(3.7) Enthalpy Data from the Chao-Seader Correlation

The partial molar enthalpies relative to the ideal gas are calculated from thermodynamic relationships and the Redlich Kwong equation of state. The zero enthalpy datum was taken by Erbar, et. al.⁽¹⁶⁾ as ideal gas at 0°R. Ideal gas state enthalpies are evaluated from the cubic equations in temperature °F.⁽³⁾ Then, temperature derivatives of the fugacity and activity coefficients of the Chao-Seader correlation are used in the appropriate thermodynamic relationships to calculate the effect of pressure, temperature and composition on the enthalpy of the liquid phase.

The modification of the Chao-Seader correlation to predict enthalpy data as developed by Edmister, Persy and Erbar⁽¹⁵⁾ and Erbar⁽¹⁶⁾ is summarized in the following equations:

The ideal partial molar heat of vapourization is given by:

$$H_i^* - H_i^\circ = - R^*T^2 \left(\frac{\partial \ln v_i^\circ}{\partial T} \right)_{P_i} \quad (3.7-1)$$

The enthalpy of mixing due to the non ideal solution, assuming excess entropy of mixing is zero is obtained from:

$$\bar{h}_i - H_i^* = - R^*T^2 \left(\frac{\partial \ln \gamma_i}{\partial T} \right)_{P,x} \quad (3.7-2)$$

ΔH from the ideal gas to the solution mixture is then calculated from the sum of equation 3.7-1 and 3.7-2.

$$\bar{h}_i - H_i^\circ = - R^*T^2 \left\{ \left(\frac{\partial \ln v_i^\circ}{\partial T} \right)_{P_i} + \left(\frac{\partial \ln \gamma_i}{\partial T} \right)_{P_i, x} \right\} \quad (3.7-3)$$

" \bar{h}_i " the partial molar enthalpy of component "i" in the liquid is, therefore:

$$\bar{h}_i = H^\circ_i - R^* T_R^2 T_C \left\{ \left(\frac{\partial \ln v_i^\circ}{\partial T_R} \right)_{P_i} + \left(\frac{\partial \ln \gamma_i}{\partial T_R} \right)_{P_{i,x}} \right\} \quad (3.7-4)$$

Where the temperature derivatives of the fugacity and the activity coefficients as obtained from the Chao-Seader correlation are:

$$\left(\frac{\partial \ln \gamma_i}{\partial T_R} \right)_{P_{i,x}} = \frac{V_i^*}{R^* T_R^2 T_C} (\delta_i - \bar{\delta}_m)^2 \quad (1.8) \quad (3.7-5)$$

$$\begin{aligned} \left(\frac{\partial \ln v_i^\circ}{\partial T_R} \right)_{P_i} = & 2.303 \left\{ -\frac{A_2}{T_R^2} + A_3 + 2A_4 T_R + 3A_5 T_R^2 + (A_7 + 2A_8 T_R) P_R \right. \\ & \left. + A_{10} P_R^2 + \omega_i \left(A_{12} - \frac{A_{12}}{T_R^2} + 3A_{14} T_R^3 \right) \right\} \end{aligned} \quad (3.7-6)$$

the molar enthalpy of the liquid mixture is then:

$$h = \sum_{i=1}^c x_i \bar{h}_i \quad (3.7-7)$$

The molar enthalpy of the gas phase mixture as derived from the Redlich-Kwong equation of state is:

$$H = \sum_{i=1}^c y_i H^\circ_i - \left[\frac{3}{2} \frac{A^2}{B} \ln \left(1 + \frac{BP}{Z} \right) + 1 - Z \right] \quad (3.7-8)$$

(4) Description of Computer Programs

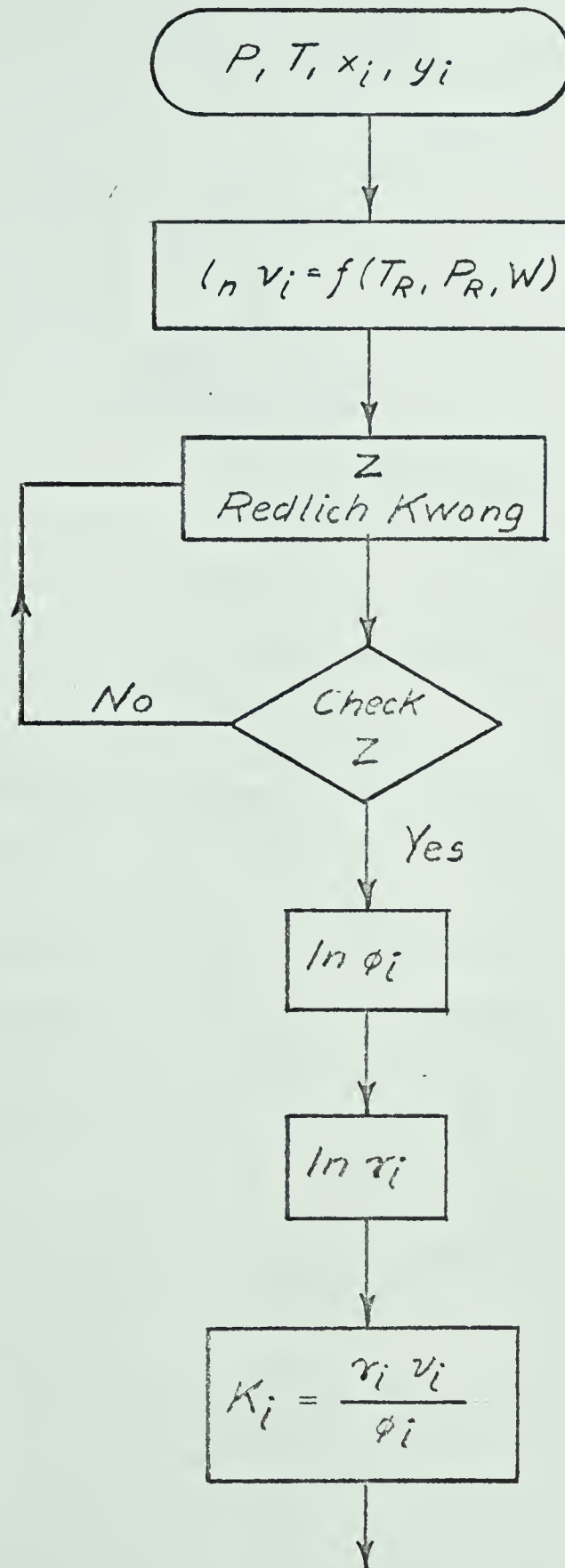
(4.1) Chao-Seader Correlation and Data

Throughout the programs, except when otherwise specified, the Chao-Seader generalized, methane and hydrogen constants, as tabulated in appendix III, table I, and carbon dioxide, hydrogen sulfide and nitrogen constants calculated by Erbar and Edmister⁽¹⁸⁾, presented in appendix III, table III, were used. Other necessary Chao-Seader correlation data was taken from the data supplied by Erbar^(16,18) with the N.G.P.A. flash, bubble and dew point computer program.

When hypothetical components were considered the required Chao-Seader data was calculated by the method proposed by Cavett⁽⁸⁾ as modified by Erbar⁽¹⁶⁾. A summary of this method is also presented in appendix III.

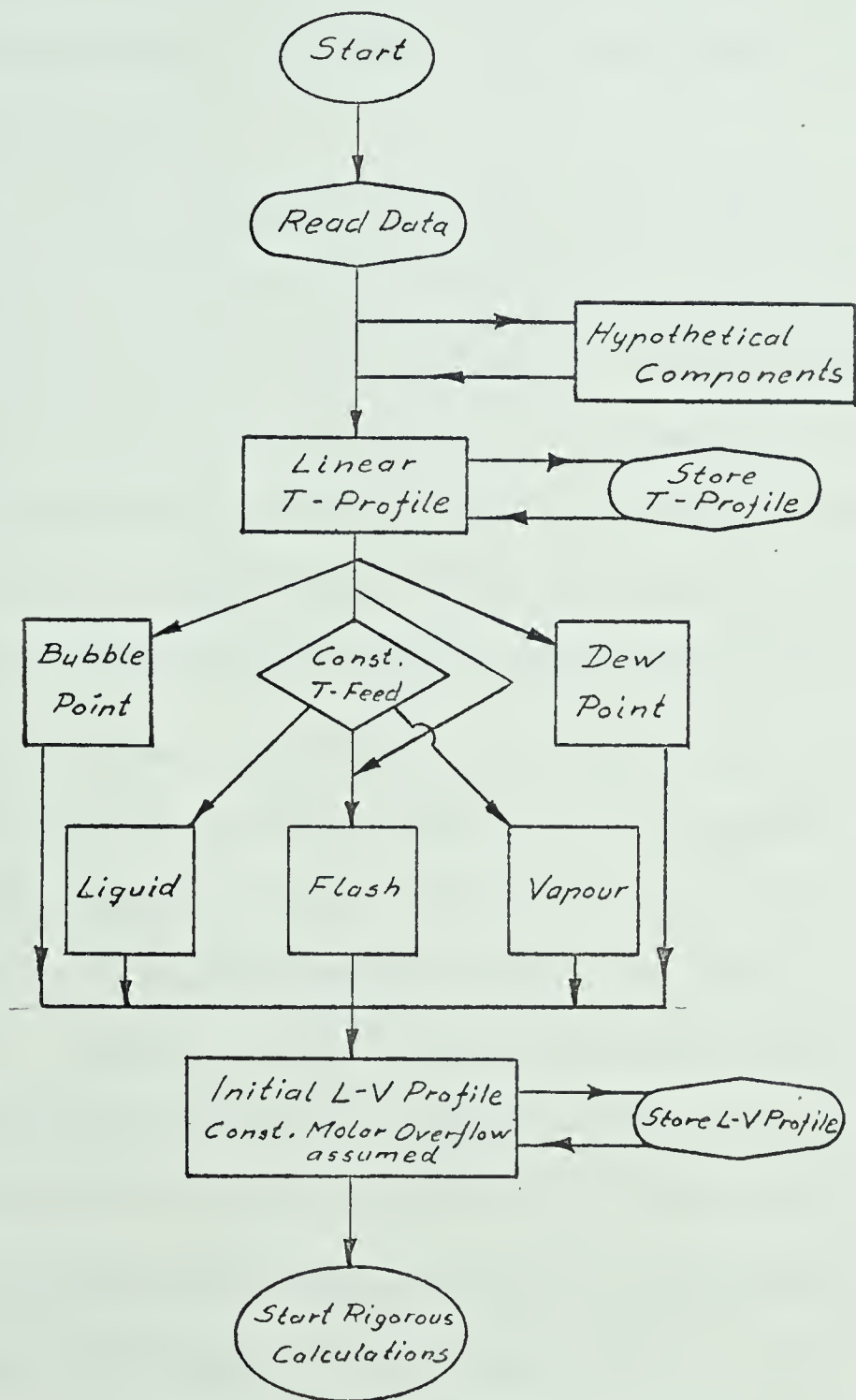
A simplified flow diagram of the Chao-Seader K-ratio calculational procedure is presented in figure II. The stage temperature and stage compositions needed to start the calculation are taken from the previous trial. Natural logs of the liquid fugacity coefficients, equivalent to the natural logs of the ideal K-ratios, are calculated first from the expressions in T_R , P_R and ω . The Redlich and Kwong equation of state is then solved for the compressibility factor Z . Being an implicit function in Z it is solved iteratively for Z by the computational forcing technique of interval halving. Having obtained Z , the natural logs of the liquid activity coefficients γ_i and the vapour fugacity coefficients ϕ_i are calculated. The K-ratios are then directly obtained from γ_i , ϕ_i and v_i° .

FIGURE II



CHAO SEADER K-RATIO
CALCULATION PROCEDURE

FIGURE III



PRELIMINARY COMPUTER
CALCULATIONS

(4.2) Thiele-Geddes Computer Program

The necessary data to be read in is; the column specifications as described in table II, the component Chao-Seader data for the K-ratio and H-value correlations and the approximate feed, distillate, and bottoms temperatures. The format of the input data is described in detail in appendix III.

To start the rigorous calculations, some computer precalculations are required as shown in the flow diagram in figure III. A linear temperature profile is first estimated. The feed condition, which can be specified as (i) bubble point, (ii) dew point, (iii) constant fraction liquid flash and (iv) constant temperature feed, is then calculated. Initial liquid-vapour profiles can then be estimated from the assumption of constant molar overflow and the feed condition.

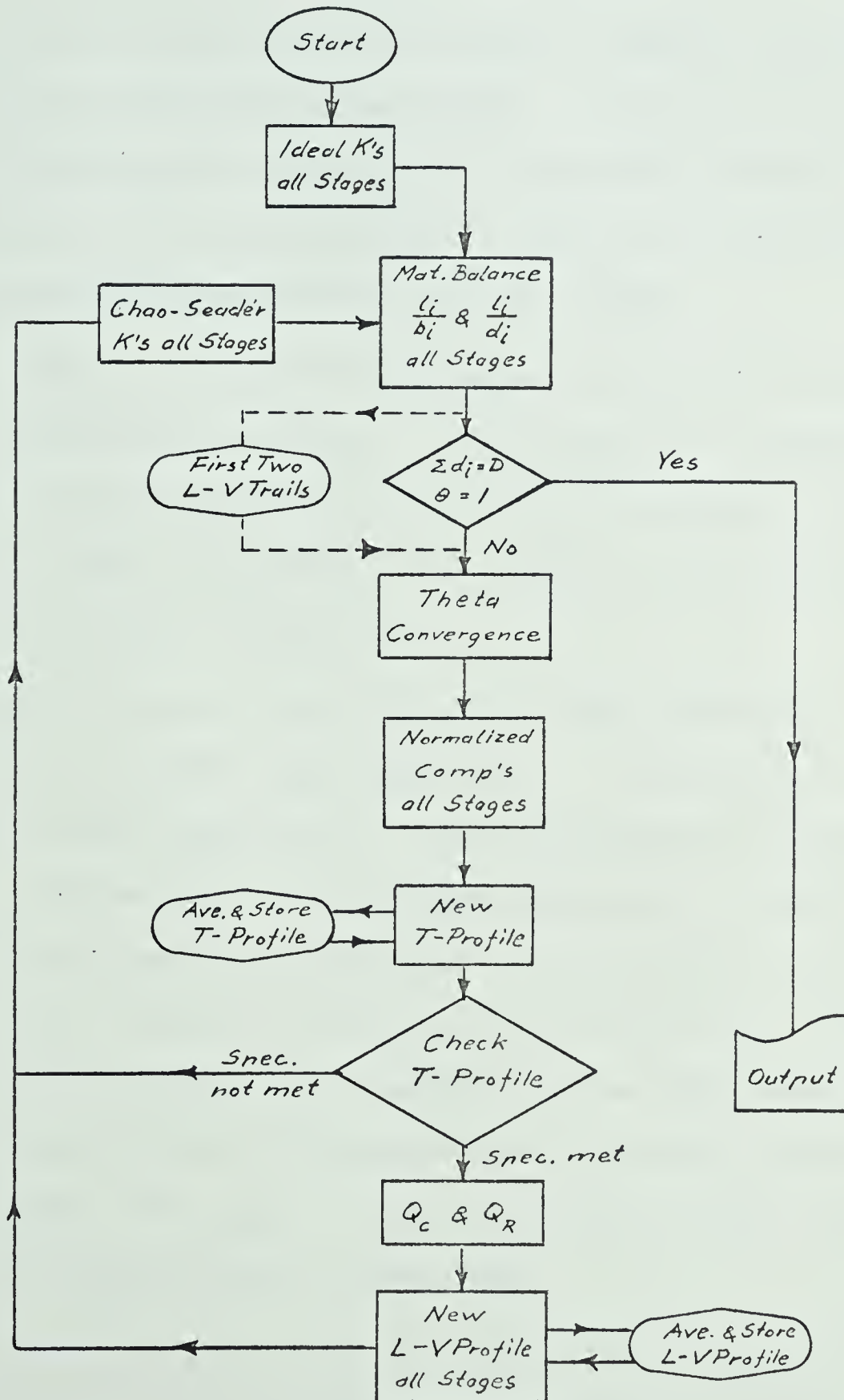
Figure IV shows a simplified flow diagram of the Thiele-Geddes program. For the first iteration, because no stage compositions are available, ideal K-ratios are used. These are merely the calculated pure component liquid fugacity coefficients ν_i° , as described in section 3.6(a). The Thiele-Geddes iterative method groups the equations representing the distillation column by type, as illustrated in figure IV, and solves one type of equation at a time for the whole column.

From the material balances down and up the column the ratios l_i/d_i and l_i/b_i are obtained. A convergence check is then made on the calculated distillate and theta. This convergence check is bypassed in the first two trials of new liquid and vapour profiles. The normalized stage compositions are then calculated from which the new temperature

profile is obtained by the "bubble point" method. This temperature profile is checked to make sure that it has converged sufficiently. If any stage temperature differs by more than ten degrees from that previously calculated, the material balances are recalculated and the temperature profile correction is repeated. When the temperature profile has stabilized, the reboiler and condenser heat loads and the new vapour-liquid profiles are calculated. The column calculations are then repeated for the new vapour-liquid profiles until the convergence criteria are satisfied or for twenty-five trials of new vapour liquid profiles.

The theta method of convergence as applied to this program is described in section 3.4. Also, the required forcing constraints to ensure convergence of the solutions are discussed in section 4.4.

FIGURE IV



THIELE - GEDDES PROGRAM

(4.3) Modified Bergamini's Approach Computer Program

The data is read in and the preliminary computer calculations are performed as in the Thiele-Geddes program. Assumed distillate and bottoms compositions is the only additional information that must be read in for this calculational procedure. Figure III therefore also describes the required precalculations for this program.

In figure V a simplified flow diagram illustrates the modified Bergamini's calculational procedure. In this approach the equations representing the mathematical model of the distillation column are solved stage by stage. These equations as applied to this calculational procedure are described in section 3.3.

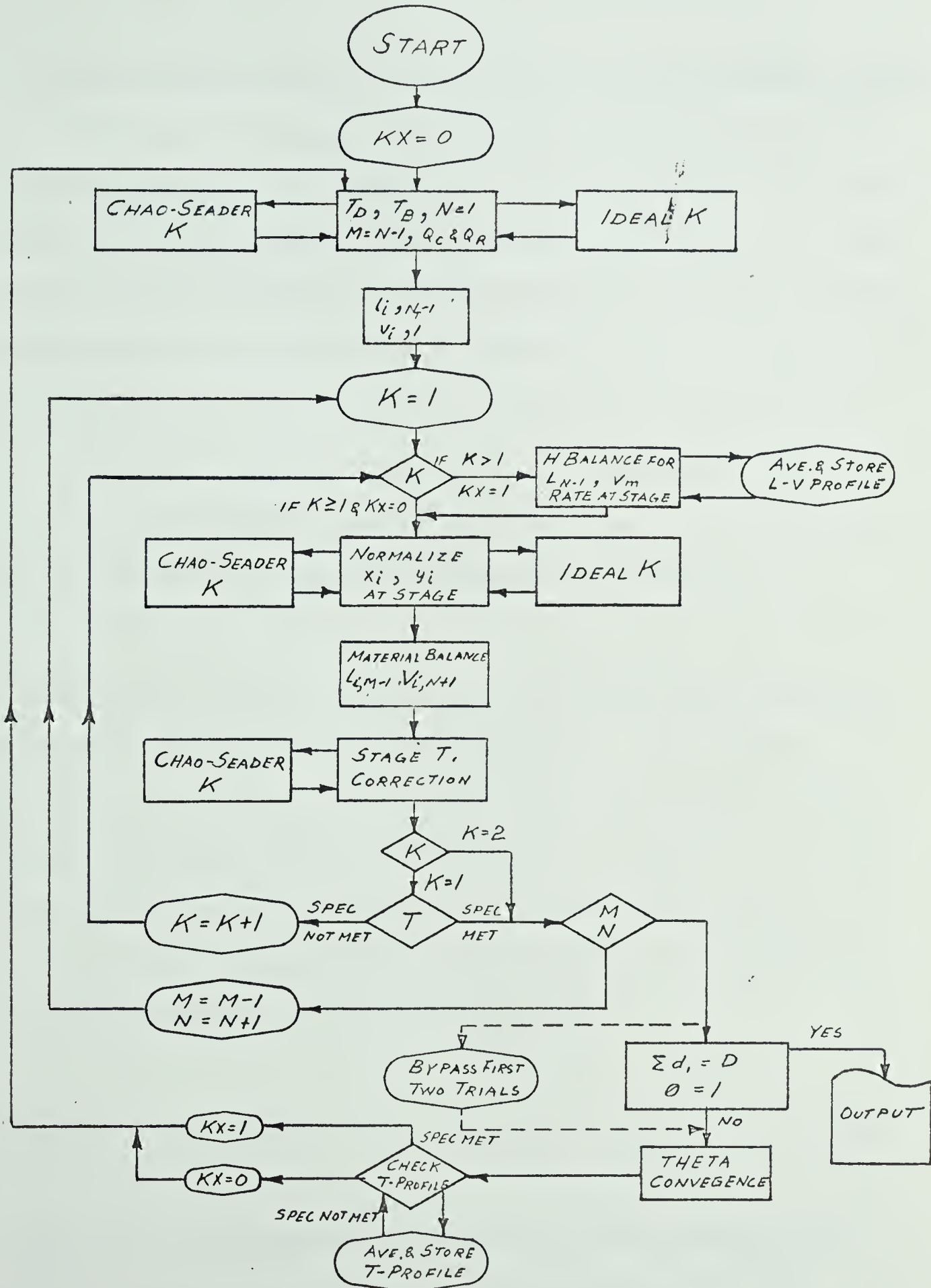
Ideal K-ratios are used in the first column iteration to estimate the first set of column stage compositions. The material balances provide a set of stage compositions. The stage temperature is then calculated. Only two trials for the stage temperature are permitted. If the temperature convergence restriction is not satisfied the stage temperature is then estimated on the basis of these two trials. No corrections on the flow rates are attempted until the temperature profile has stabilized to within five degrees from the previous calculation on all stages. The stage by stage calculations are made from both ends of the column towards the feed stage.

The distillate and " θ " are then checked for convergence of the column solution. As in the Thiele-Geddes program, this convergence check is bypassed for the first two trials of new liquid and vapour profiles. A check is then made on the oscillation in the temp-

perature profile before the calculations are repeated for the whole column. If the convergence criteria cannot be satisfied a maximum of twenty-five trials at new liquid-vapour profiles are permitted and the results of the last iteration are printed.

As in the Thiele-Geddes program the theta method of convergence, section 3.4. and the forcing constraints required to ensure convergence, section 4.4. are used.

FIGURE V



MODIFIED BERGAMINI'S METHOD

(4.4) Fenske-Underwood-Erbar and Maddox Short Cut Design Computer Program

The short cut design program was written on the basis of the split being specified on two components. To start the short cut design calculations a rough estimate of the column split is first made. Also, an approximate feed temperature from which the first distillate and bottom temperatures are estimated must be read in, $T_D = T_F + 50$, $T_B = T_F - 50$. The Chao-Seader input data are read in as described in appendix III.

The Fenske equation 3.5-1 or 3.5-2 is then solved for the total reflux at the specified splits on the key components. The criterion for convergence of the Fenske equations solutions is:

$$\text{Abs } (\sum x_{i,D} - 1) \leq 1.0 \times 10^{-4} \quad (4.4-1)$$

Next, the Underwood equation 3.5-8 which relates the thermal condition of the feed to the root theta is solved for theta. The solution for θ , where $\alpha_{lk} < \theta < \alpha_{hk}$, is achieved by the Golden-Section search. This search technique, which is fully described by Wilde⁽⁶⁵⁾, requires starting boundary values and converges on the specified limit of error. In the case of this program, the objective function and the convergence criterion for the Underwood equation solution is:

$$\sum_{i=1}^c \frac{\alpha_i X_{if}}{\alpha_i - \theta} - 1 + q \leq 1.0 \times 10^{-4} \quad (4.4-2)$$

The theta so obtained together with the top and bottom compositions, calculated by the Fenske equation, are then substituted into the Underwood equations, 3.5-5, representing the rectifying section of the column, and 3.5-6, representing the stripping section, to solve for the

minimum reflux. Due to the assumptions involved the stripping section minimum reflux differs from the rectifying section minimum reflux. The larger of the two is taken as the minimum reflux for the column. The operating reflux is then obtained by multiplying the minimum reflux by a factor 1.2 to 1.5. For this program 1.3 was used.

The Erbar and Maddox charts of (L_0/V_1) vs (N_m/N) at various $(L_0/V_1)_{\min}$ are then interpolated to obtain the required number of theoretical stages. The set of plots corresponding to Underwood's method of obtaining the minimum reflux are read into the computer in the form of a twenty-one point three dimensional grid. The (N_m/N) ratio is then obtained for the set of $(L_0/V_1)_{\text{operating}}$, and $(L_0/V_1)_{\min}$ by (a) linear, or (b) lagrangian three dimensional interpolation schemes. The grid is fine enough so that the simple linear interpolation is of sufficient accuracy for the short cut method programmed. Originally the Erbar and Maddox charts were developed for a bubble point feed. Equation 3.5-11 was then developed later to modify the reflux rate when a feed other than a bubble point feed was specified.

The feed stage location for the short cut design approach is assumed to be at the optimum point. For practical purposes, the feed stage was selected arbitrarily to fall on the stage whose temperature was nearest the feed temperature assuming a linear temperature profile. The approximate distillate rate, reflux ratio, the number of theoretical stages and the feed stage location, estimated from the short cut, were then used as first guess in the rigorous Thiele-Geddes or the modified Bergamini's approach programs. These rigorous proced-

ures were programmed in the form of subroutines to be used together with the short cut program.

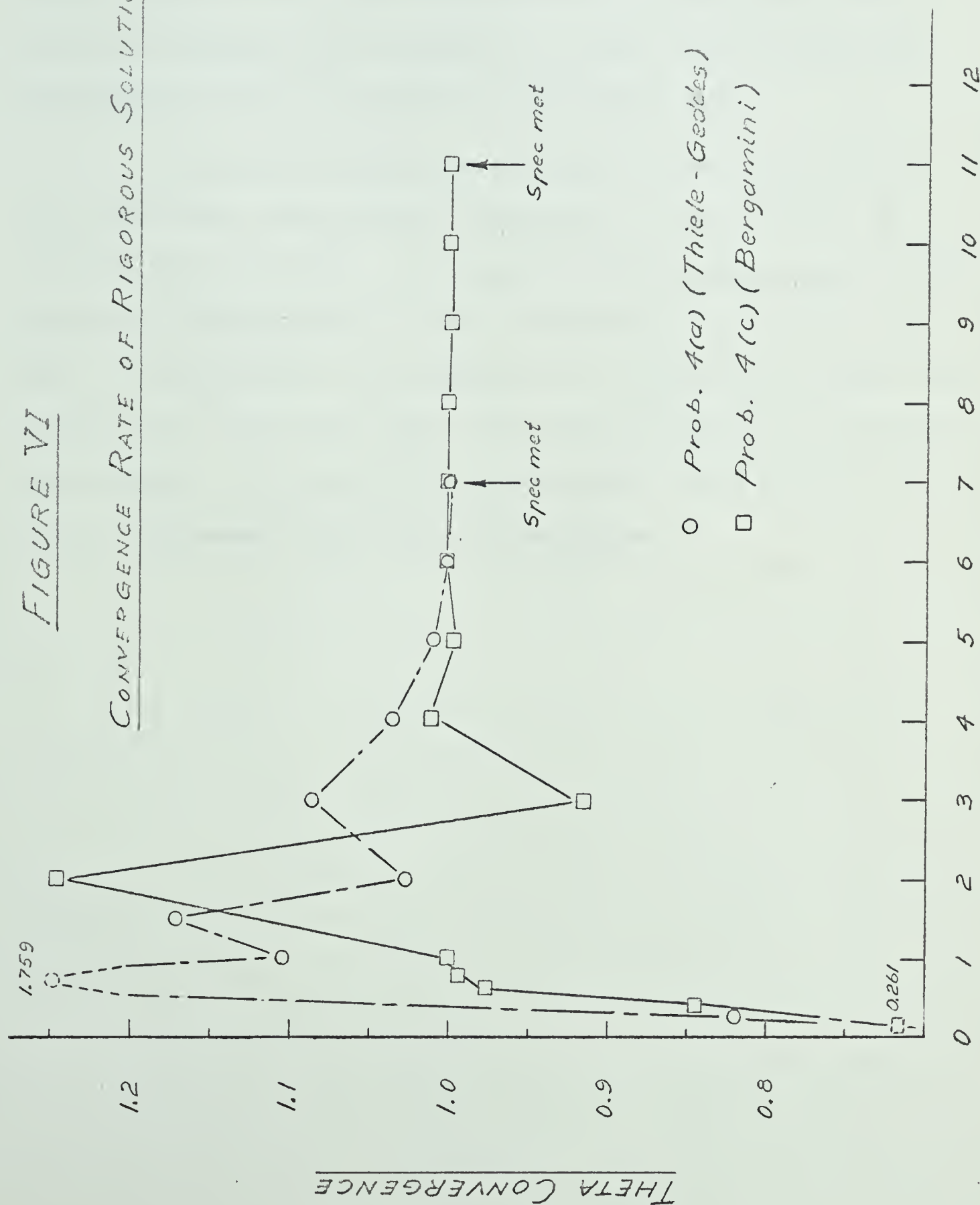
(4.5) Convergence Forcing Constraints

Lyster, Sullivan, Billingsley and Holland^(26,35) found that the temperature and rate profiles tended to oscillate around the correct profiles, and that the solution to the rigorous distillation problems would not always converge on the desired specifications. This was particularly true for wide boiling feeds. The rate of convergence could be significantly increased, as shown by Holland, and the region of the stability of solution could be extended, as demonstrated by Friday and Smith⁽²¹⁾, if these oscillations were dampened.

The swing of the temperature profile, in the programs developed in this thesis, was reduced by averaging the previous with the newly calculated profile. To increase the stability of the flow rates' profiles, a limit of ten degrees was set on the maximum temperature change permitted at any stage between successive iterations before attempting a correction on the liquid-vapour rate profiles. Calculations were, therefore, carried out at constant flow rates until the temperature profile had stabilized to the ten degree limit.

The vapour and liquid profiles were found to be quite sensitive to temperature change and condenser-reboiler heat loads. As a result, to ensure convergence for a large variety of problems, a tight control was kept on the liquid-vapour profiles. The maximum change was not permitted to exceed more than twenty percent of the previous flow rate, and in addition to this the profiles were averaged to dampen oscillations. The combined restrictions permitted a maximum of ten percent variation between any successive set of liquid-vapour profiles.

FIGURE VI
CONVERGENCE RATE OF RIGOROUS SOLUTIONS



VAPOUR-LIQUID PROFILE TRIAL

(4.6) Compiler Language

The programs were developed on the 7040 I.B.M. computer at the University of Alberta. They are written in Fortran IV compiler language, version nine. This version has particular output control characters which may not be acceptable to other Fortran versions and the output may have to be adapted to the system in use.

Floating point trap error messages were encountered on the b_i/d_i ratio when columns having large number of stages and wide boiling feeds were calculated. As a result a floating point error message suppression subroutine FPT 9, which is peculiar to version nine, was used. This subroutine is not applicable to other Fortran versions and may have to be substituted with a corresponding floating point suppression routine. An alternative is to put control limits on the ratio b_i/d_i as programmed in the Thiele-Geddes program.

(5) Example Problems

(5.1) Example Problem Method Comparison

Example Problem 1

A ten theoretical stage butane-pentane splitter the solutions of which are published by Smith and also by Holland, is considered. The feed enters at the fifth stage at its bubble point having the following composition:

<u>Component</u>	<u>Mole Fractions in Feed</u>
C ₃	0.05
i - C ₄	0.15
n - C ₄	0.25
i - C ₅	0.20
n - C ₅	0.35

The operating conditions are to be:

D/F ratio	=	0.489
Reflux ratio	=	2.579
Column pressure	=	120 psia.

The rigorous calculations were made using the Thiele-Geddes and Bergamini procedures with both Polynomial and Chao-Seader data. For the Thiele-Geddes programs an estimate of condenser temperature 160°F. and bottom temperature 234°F. was made. In the Bergamini calculations an additional estimate of top and bottom composition was necessary as well as the condenser and bottoms temperature.

The methods compared are:

(1A) Thiele-Geddes method with bottom up enthalpy balances and Chao-Seader K-ratios and enthalpies.

(1B) Thiele-Geddes procedure with enthalpy balances from both ends of column and Chao-Seader K-ratio and enthalpies.

(1C) Bergamini calculation procedure with Chao-Seader K-ratios and enthalpies.

(1D) Bergamini calculation procedure, Chao-Seader K-ratios, and polynomial H values from Holland.*

(1E) Thiele-Geddes method with bottom up enthalpy balances, Chao-Seader K-ratios and polynomial enthalpies from Holland.*

(1F) Thiele-Geddes method with bottom up enthalpy balances and polynomial K-ratios and enthalpies from Holland.*

(1G) Thiele-Geddes calculation procedure with enthalpy balances from both ends of column and polynomial K-ratios and enthalpies from Holland.*

(1H) Bergamini calculation procedure with polynomial K-ratios and enthalpies from Holland.*

(1I) Values obtained from the sample problems in Smith.**

(1J) "Example", Holland, et. al. (***, *)

* C.D. Holland, "Multicomponent Distillation", pp. 494, 496, Prentice-Hall (1963), (table A-2* and table A-6**).

- ** B.D. Smith, "Design of Equilibrium Stage Processes", pp. 342, McGraw-Hill Co. Inc., New York (1963).
- *** W.N. Lyster, S.L. Sullivan Jr., D.S. Billingsley and C.D. Holland, Petroleum Refiner, 38 (6), 221-30 (1959).
- + Scheibel, G.H. and F.J. Jenny, "Representation of Equilibrium Constant Data", Ind. Eng. Chem. 37, 80 (1945).
- ++ Maxwell, J.B., "Data Book on Hydrocarbons", D. Van Nostrand, New York, (1955).

Table Ex 1-I

	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J
Condenser temp. °F.	147.7	147.7	147.7	147.7	147.7	147.5	147.6	147.6	—	147.63
Condenser load BTU/lb mole feed	1.450x10 ⁴	1.450x10 ⁴	1.450x10 ⁴	1.507x10 ⁴	1.507x10 ⁴	1.512x10 ⁴	1.512x10 ⁴	1.512x10 ⁴	—	—
Reboiler load BTU/lb mole feed	1.496x10 ⁴	1.496x10 ⁴	1.496x10 ⁴	1.558x10 ⁴	1.559x10 ⁴	1.561x10 ⁴	1.561x10 ⁴	1.561x10 ⁴	—	—
Feed temp. °F.	183.2	183.2	183.2	183.2	183.2	184.7	184.7	184.7	185	—

Table Ex 1-II

Top Product Compositions in Mole Fractions

Method	C ₃			i-C ₄		n-C ₄	i-C ₅		n-C ₅
1A	1.022x10 ⁻¹			2.995x10 ⁻¹		4.714x10 ⁻¹	7.185x10 ⁻²		5.503x10 ⁻²
1B	1.022x10 ⁻¹			2.995x10 ⁻¹		4.715x10 ⁻¹	7.184x10 ⁻²		5.500x10 ⁻²
1C	1.022x10 ⁻¹			2.994x10 ⁻¹		4.714x10 ⁻¹	7.188x10 ⁻²		5.501x10 ⁻²
1D	1.022x10 ⁻¹			2.995x10 ⁻¹		4.717x10 ⁻¹	7.175x10 ⁻²		5.486x10 ⁻²
1E	1.022x10 ⁻¹			2.995x10 ⁻¹		4.717x10 ⁻¹	7.174x10 ⁻²		5.483x10 ⁻²
1F	1.022x10 ⁻¹			3.000x10 ⁻¹		4.722x10 ⁻¹	7.252x10 ⁻²		5.309x10 ⁻²
1G	1.022x10 ⁻¹			3.000x10 ⁻¹		4.722x10 ⁻¹	7.252x10 ⁻²		5.309x10 ⁻²
1H	1.022x10 ⁻¹			3.000x10 ⁻¹		4.723x10 ⁻¹	7.250x10 ⁻²		5.305x10 ⁻²
1I	1.025x10 ⁻¹			2.99x10 ⁻¹		4.63x10 ⁻¹	7.30x10 ⁻²		5.34x10 ⁻²
1J	1.022x10 ⁻¹			3.000x10 ⁻¹		4.724x10 ⁻¹	7.285x10 ⁻²		5.335x10 ⁻²

Table Ex 1-III

Bottom Product Compositions in Mole Fractions

Method	C ₃	i-C ₄	n-C ₄	i-C ₅	n-C ₅
1A	4.690x10 ⁻⁵	6.596x10 ⁻³	3.808x10 ⁻²	3.226x10 ⁻¹	6.322x10 ⁻¹
1B	4.686x10 ⁻⁵	6.950x10 ⁻³	3.805x10 ⁻²	3.226x10 ⁻¹	6.323x10 ⁻¹
1C	4.711x10 ⁻⁵	6.973x10 ⁻³	3.813x10 ⁻²	3.226x10 ⁻¹	6.322x10 ⁻¹
1D	4.641x10 ⁻⁵	6.904x10 ⁻³	3.787x10 ⁻²	3.227x10 ⁻¹	6.324x10 ⁻¹
1E	4.641x10 ⁻⁵	6.900x10 ⁻³	3.784x10 ⁻²	3.227x10 ⁻¹	6.325x10 ⁻¹
1F	4.626x10 ⁻⁵	6.494x10 ⁻³	3.732x10 ⁻²	3.220x10 ⁻¹	6.341x10 ⁻¹
1G	4.628x10 ⁻⁵	6.497x10 ⁻³	3.734x10 ⁻²	3.220x10 ⁻¹	6.341x10 ⁻¹
1H	4.616x10 ⁻⁵	6.483x10 ⁻³	3.728x10 ⁻²	3.220x10 ⁻¹	6.342x10 ⁻¹
1I	4.5 x10 ⁻⁵	6.46 x10 ⁻³	3.72 x10 ⁻²	3.21 x10 ⁻¹	6.34 x10 ⁻¹
1J	5.114x10 ⁻⁵	6.47 x10 ⁻³	3.714x10 ⁻²	3.21 x10 ⁻¹	6.334x10 ⁻¹

Table Ex 1-IV

Vapour Profiles for Example 1

Stage	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J
1	1.754	1.750	1.750	1.750	1.750	1.752	1.750	1.750	1.75	1.75
2	1.710	1.708	1.706	1.709	1.708	1.708	1.706	1.707	1.71	1.706
3	1.675	1.674	1.672	1.675	1.675	1.672	1.672	1.676	1.67	1.674
4	1.653	1.652	1.650	1.653	1.654	1.657	1.654	1.657	1.65	1.656
5	1.641	1.641	1.640	1.643	1.643	1.647	1.646	1.647	1.645	1.648
6	1.643	1.643	1.640	1.649	1.650	1.653	1.654	1.655	1.65	1.657
7	1.647	1.647	1.644	1.657	1.657	1.662	1.663	1.664	1.66	1.666
8	1.652	1.652	1.650	1.666	1.665	1.672	1.672	1.673	1.67	1.675
9	1.659	1.659	1.648	1.674	1.674	1.681	1.681	1.682	1.68	1.684
10	1.666	1.667	1.669	1.679	1.682	1.687	1.688	1.689	1.69	1.691

Table Ex 1-V

Temperature Profile for Example 1

Stage	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J
1	164.7	164.7	164.7	164.9	164.7	165.6	165.6	165.6	165.5	165.7
2	177.6	177.6	177.6	177.6	177.6	179.3	179.3	179.3	179	179.40
3	187.7	187.7	187.7	187.7	187.7	189.9	189.9	189.8	189.5	189.90
4	195.1	195.1	195.1	195.2	195.1	197.4	197.4	197.3	197	197.38
5	200.1	200.1	200.1	200.1	200.2	202.3	202.3	202.3	202	202.30
6	209.2	209.3	209.2	209.1	209.3	211.5	211.5	211.5	211	211.56
7	217.1	217.1	217.1	217.1	217.2	219.3	219.3	219.3	219	219.32
8	223.5	223.5	223.5	223.5	223.6	225.6	225.6	225.6	225.5	225.60
9	228.6	228.6	228.8	228.4	228.6	230.5	230.4	230.4	230	230.45
10	232.4	232.4	232.4	232.4	232.4	234.1	234.1	234.1	234	234.09

Table Ex 1-VI *

Computer Object Time (sec.)

1A	1B	1C	1D	1E	1F	1G	1H	1I	1J
84	50	49	30	43	16	21	17	--	--

Table Ex 1-VII

Convergence Criterion

	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J
Abs. (E-D spec)	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-4}	5.0×10^{-4}	5.0×10^{-4}	5.0×10^{-4}	5.0×10^{-4}	1.0×10^{-4}	--	$\Delta D/D \leq \pm .01$
Abs. (1-theta)	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}	1.0×10^{-3}	--	--

* Time required to do the actual calculations (Fortran time not included). This time is a relative measure and is dependent on the individual computer system.

Example Problem 2

Example "2" was taken from the published example problem of Stocking, Erbar and Maddox*.

The problem specifications are:

-16 ideal stage column, including reboiler

-D/F ratio = 0.27027

-200 psia. column pressure

-reflux ratio = 2.7

-total condenser

-feed entering at 150°F. with the following composition :

<u>Component</u>	<u>Concentration in Mole Fraction</u>
C ₂ H ₆	0.00271
C ₃ H ₈	0.26695
i-C ₄	0.08923
n-C ₄	0.34170
i-C ₅	0.08863
n-C ₅	0.09992
C ₆	0.08017
C ₇	0.03069

* Stocking, M., J.H. Erbar and R.N. Maddox, Ref. Engr. (Section of Petroleum Engineer), 32 (4), C-15 (1960).

The methods of calculation and data sources are:

(2A) Thiele-Geddes calculation procedure using Chao-Seader data.

(2B) Stocking, et. al., results using 1957 N.G.S.M.A. data book for K-ratio data and Kellog enthalpies, also from the 1957 N.G.S.M.A. data book.

(2C) Stocking, et. al., results using Winn K-ratios and Kellog enthalpy data from the 1957 N.G.S.M.A. data book.

Table Ex 2-I

	2A	2B	2C
Condenser Temp. °F.	110.7	101.2	101.3
Condenser Heat Load BTU/lb mole feed	6.332×10^3	5.77×10^3	7.93×10^3
Reboiler Heat Load BTU/lb mole feed	8.324×10^3	7.50×10^3	7.76×10^3
Feed Temp. °F.	150.0	150.0	150.0

Table Ex 2-II

Top Product Compositions in Mole Fractions

Method	2A	2B	2C
Component			
C ₂ H ₆	1.003×10^{-2}	1.009×10^{-2}	1.009×10^{-2}
C ₃ H ₈	9.117×10^{-1}	9.309×10^{-1}	9.488×10^{-1}
i-C ₄	4.690×10^{-2}	4.492×10^{-2}	3.145×10^{-2}
n-C ₄	3.137×10^{-2}	1.410×10^{-2}	9.69×10^{-3}
i-C ₅	2.730×10^{-5}	----	----
n-C ₅	5.505×10^{-6}	----	----
C ₆	2.727×10^{-9}	----	----
C ₇	1.348×10^{-12}	----	----

Table Ex 2-III

Bottom Product Compositions in Mole Fractions

Method	2A	2B	2C
Component			
C ₂ H ₆	3.404×10^{-7}	----	----
C ₃ H ₈	2.815×10^{-2}	2.319×10^{-2}	1.658×10^{-2}
i-C ₄	1.049×10^{-1}	1.055×10^{-1}	1.105×10^{-1}
n-C ₄	4.566×10^{-1}	4.620×10^{-1}	4.636×10^{-1}
i-C ₅	1.214×10^{-1}	1.212×10^{-1}	1.212×10^{-1}
n-C ₅	1.369×10^{-1}	1.366×10^{-1}	1.366×10^{-1}
C ₆	1.099×10^{-1}	1.096×10^{-1}	1.096×10^{-1}
C ₇	4.206×10^{-2}	4.196×10^{-2}	4.196×10^{-2}

Table Ex 2-IV

Vapour Profiles

Stage	2A	2B	2C
1	1.000	1.000	1.000
2	.979	.980	.982
3	.956	.955	.957
4	.935	.927	.927
5	.919	.902	.897
6	.907	.881	.874
7	.897	.866	.858
8	.882	.849	.842
9	.850	.784	.774
10	1.002	.814	.810
11	1.007	.821	.823
12	1.014	.831	.844
13	1.022	.847	.872
14	1.031	.868	.905
15	1.033	.886	.932
16	1.008	.880	.931

Table Ex 2-V

Temperature Profiles (°F.)

Stage	2A	2B	2C
1	117.1	103.3	102.9
2	124.5	105.8	104.8
3	133.1	109.3	108.0
4	141.8	113.9	112.4
5	149.4	119.1	117.7
6	155.8	124.3	123.1
7	161.3	129.4	128.3
8	167.7	135.6	134.5
9	179.0	148.1	147.9
10	183.5	152.6	154.3
11	188.6	158.3	162.1
12	194.3	165.1	170.8
13	200.3	172.8	180.0
14	206.8	181.4	189.7
15	215.1	192.9	202.5
16	230.9	212.6	228.1

Table Ex 2-VI

	<u>Computer Object Time (sec.)</u>		
Method	2A	2B	2C
Seconds	133	--	--

Table Ex 2-VII

	<u>Convergence Criterion</u>		
	2A	2B	2C
Abs. (D-D spec)	1.0×10^{-4}	--	--
Abs. (1-theta)	1.0×10^{-3}	--	--

Example Problem 3

In example 3 a column having a split feed and a partial condenser is considered.

The specifications for example 3 are as follows:

-D/F ratio = 0.31

-reflux ratio = 2.71

-partial condenser

-column pressure = 300 psia.

-number of theoretical stages = 12

-feed stage location = 6

The feed is entering at 0.8 fraction liquid and is of the following composition:

<u>Component</u>	<u>Mole Fraction in Feed</u>
CH ₄	0.02
C ₂ H ₆	0.10
C ₃ H ₈	0.15
i-C ₄	0.08
n-C ₄	0.15
n-C ₅	0.15
C ₆	0.15
C ₇	0.15
	0.20

(2A) Thiele-Geddes calculation procedure Chao-Seader K and H values.

(2B) Bergamini rigorous method and Chao-Seader K-ratios and H values.

(2C) Thiele-Geddes calculation procedure polynomial K and H values from Holland*

* C.D. Holland, "Multicomponent Distillation", 495, 497, Prentice-Hall (1963), (tables A-4⁺ and A-8⁺⁺)

+ Hadden, S.T., "Vapour Liquid Equilibria in Hydrocarbon Systems", Chem. Eng. Progr., 44, 37 (1948).

++ Maxwell, J.B., "Data Book on Hydrocarbons", D. Van Nostrand, New York (1955).

Table Ex 3-I

Method	3A	3B	3C
Condenser Temp. °F.	129.9	129.9	127.0
Condenser Heat Load BTU/lb mole feed	5.661 x 10 ³	5.661 x 10 ³	5.670 x 10 ³
Reboiler Heat Load BTU/lb mole feed	8.772 x 10 ³	8.771 x 10 ³	9.268 x 10 ³
Feed Temperature °F.	242.6	242.6	242.6

Table Ex 3-II
Top Product Compositions in Mole Fraction

Method	3A	3B	3C
Component			
CH ₄	0.6452 x 10 ⁻¹	0.6452 x 10 ⁻¹	0.6451 x 10 ⁻¹
C ₂ H ₆	0.3225	0.3225	0.3225
C ₃ H ₈	0.4606	0.4607	0.4742
i-C ₄	0.8987 x 10 ⁻¹	0.8985 x 10 ⁻¹	0.9810 x 10 ⁻¹
n-C ₄	0.6207 x 10 ⁻¹	0.6200 x 10 ⁻¹	0.4065 x 10 ⁻¹
n-C ₅	0.4511 x 10 ⁻³	0.4495 x 10 ⁻³	0.5709 x 10 ⁻⁴
C ₆	0.3228 x 10 ⁻⁵	0.3313 x 10 ⁻⁵	0.9875 x 10 ⁻⁷
C ₇	0.5206 x 10 ⁻⁷	0.5178 x 10 ⁻⁷	0.3480 x 10 ⁻⁹

Table Ex 3-III
Bottom Product Composition in Mole Fractions

Method	3A	3B	3C
Component			
CH ₄	.3532 x 10 ⁻⁷	.3529 x 10 ⁻⁷	.7511 x 10 ⁻⁹
C ₂ H ₆	.2898 x 10 ⁻⁴	.2877 x 10 ⁻⁴	.1384 x 10 ⁻⁴
C ₃ H ₈	.1046 x 10 ⁻¹	.1042 x 10 ⁻¹	.4346 x 10 ⁻²
i-C ₄	.7556 x 10 ⁻¹	.7557 x 10 ⁻¹	.7187 x 10 ⁻¹
n-C ₄	.1895	.1895	.1991
n-C ₅	.2172	.2172	.2174
C ₆	.2174	.2174	.2174
C ₇	.2899	.2899	.2899

Table Ex 3-IV
Vapour Profile

Stage	Method	3A	3B	3C
1		1.150	1.150	1.150
2		1.149	1.145	1.174
3		1.137	1.134	1.175
4		1.112	1.109	1.165
5		1.054	1.052	1.123
6		0.739	0.747	0.990
7		0.844	0.840	0.915
8		0.909	0.904	0.991
9		0.946	0.956	1.034
10		0.963	0.959	1.056
11		0.957	0.953	1.037
12		0.927	0.927	0.963

Table Ex 3-V

Temperature Profile

Method	3A	3B	3C
Stage			
1	161.0	161.0	161.7
2	177.6	177.6	178.8
3	189.2	189.1	189.7
4	200.1	200.0	198.8
5	216.8	216.6	212.7
6	250.8	251.1	248.3
7	262.7	262.8	259.5
8	271.6	271.7	267.3
9	280.1	280.2	274.7
10	291.0	291.1	285.2
11	308.7	308.6	305.1
12	339.4	339.4	346.2

Table Ex 3-VI

Computer Object Time (sec.)

Method	3A	3B	3C
seconds	87	--	41

Table Ex 3-VII

Convergence Criterion

	3A	3B	3C
Abs. (D-D spec)	1.0×10^{-4}	1.0×10^{-4}	0.3×10^{-4}
Abs. (1-theta)	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}

Example Problem 4

Example 4 was taken from the published example problem "Ex 1" by Lyster, Sullivan, Billingsley and Holland,* or example 5.7 from Holland.**

The problem specifications are:

-12 ideal stage column including reboiler

-D/F ratio of .316

-300 psia. column pressure

-reflux ratio 2.0

-partial condenser

-feed entering on the fourth stage as saturated liquid having the following compositions:

<u>Component</u>	<u>Feed Composition in Mole Fractions</u>
CH ₄	0.02
C ₂ H ₆	0.10
C ₃ H ₆	0.06
C ₃ H ₈	0.125
i-C ₄	0.035
n-C ₄	0.150
n-C ₅	0.152
C ₆	0.113
C ₇	0.090
C ₈	0.085
400 N.B.P. cut	0.070

Polynomial K-ratio and enthalpy data was taken from Holland*** (tables A4 and A8). The 400 N.B.P. cut hypothetical component data was also taken from Holland, et. al.*

The Chao-Seader data constants for the 400 N.B.P. component were calculated using the Cavett correlation⁽⁸⁾ and the hypothetical component was assumed to have the following properties:

-critical temperature of 1134.0°R.

-critical pressure of 350 psia.

-A.P.I. gravity = 46.28

-molecular weight = 146.8

** C.D. Holland, "Multicomponent Distillation", 495, 497, Prentice-Hall (1963) (tables A-4[†] and A-8⁺⁺).

* W.N. Lyster, S.L. Sullivan, Jr., D.S. Billingsley and C.D. Holland, Pet. Refiner, 38, 17, 15 (1959).

+ Hadden, S.T., "Vapour Liquid Equilibria in Hydrocarbon Systems", Chem. Eng. Progr., 44, 37 (1948).

++ Maxwell, J.B., "Data Book on Hydrocarbons", D. Van Nostrand, New York (1955).

The methods of calculation were:

(4A) Thiele-Geddes method using Chao-Seader correlation and 400 N.B.P. hypothetical component. Feed entered at its bubble point.

(4B) Thiele-Geddes method with the Chao-Seader correlation. Assuming the hypothetical component behaviour as n-decane. Feed entered at its bubble point.

(4C) Bergamini calculation procedure using the Chao-Seader correlation and 400 N.B.P. component. The feed entered at its boiling point.

(4D) Same as 4A, except feed entered as liquid feed at 175°F.

(4E) Same as 4A, except feed entered as liquid feed at 165°F.

(4F) Thiele-Geddes calculation procedure using polynomial data from Holland^(22,41).

(4G) Example problem as published by Holland^(22,*).

Table Ex 4-I

Method	4A	4B	4C	4D	4E	4F	4G
Condenser Temp. °F.	113.6	113.7	113.6	113.4	113.2	108.0	107.6
Condenser Heat Load BTU/lb mole feed	3.949x10 ³	3.952x10 ³	3.951x10 ³	3.944x10 ³	3.938x10 ³	3.992x10 ³	--
Reboiler Heat Load BTU/lb mole feed	1.161x10 ⁴	1.160x10 ⁴	1.161x10 ⁴	1.185x10 ⁴	1.222x10 ⁴	1.329x10 ⁴	1.32 x10 ⁴
Feed Temperature °F.	181.2	183.0	181.2	175.0	165.0	164.8	--

Table Ex 4-II

Top Product Compositions in Mole Fraction

Method Component	4A	4B	4C	4D	4E	4F	4G
CH ₄	.6329x10 ⁻¹	.6928x10 ⁻¹	.639x10 ⁻¹	.632x10 ⁻¹	.6329x10 ⁻¹	.6328x10 ⁻¹	.6329x10 ⁻¹
C ₂ H ₆	.3164	.3164	.3164	.3164	.3164	.3164	.3165
C ₃ H ₈	.1869	.1867	.1868	.1870	.1872	.1890	.1890
C ₃ H ₈	.3799	.3794	.3797	.3804	.3813	.3906	.3907
i-C ₄	.2242x10 ⁻¹	.2261x10 ⁻¹	.2244x10 ⁻¹	.2233x10 ⁻¹	.2220x10 ⁻¹	.2356x10 ⁻¹	.2349x10 ⁻¹
n-C ₄	.3061x10 ⁻¹	.3112x10 ⁻¹	.3076x10 ⁻¹	.3002x10 ⁻¹	.2917x10 ⁻¹	.1704x10 ⁻¹	.1700x10 ⁻¹
n-C ₅	.5038x10 ⁻³	.5192x10 ⁻³	.5085x10 ⁻³	.4818x10 ⁻³	.4506x10 ⁻³	.6356x10 ⁻⁴	.6379x10 ⁻⁴
C ₆	.7807x10 ⁻⁵	.8108x10 ⁻⁵	.7896x10 ⁻⁵	.7422x10 ⁻⁵	.6875x10 ⁻⁵	.2964x10 ⁻⁶	.2976x10 ⁻⁶
C ₇	.1970x10 ⁻⁶	.2057x10 ⁻⁶	.1994x10 ⁻⁶	.1866x10 ⁻⁶	.1719x10 ⁻⁶	.2002x10 ⁻⁸	.2001x10 ⁻⁸
C ₈	.4612x10 ⁻⁸	.4846x10 ⁻⁸	.4672x10 ⁻⁸	.4352x10 ⁻⁸	.3988x10 ⁻⁸	.1403x10 ⁻¹⁰	.1405x10 ⁻¹⁰
400 N.B.P.	.1174x10 ⁻¹⁴	.5724x10 ⁻¹¹	.1195x10 ⁻¹⁴	.1086x10 ⁻¹⁴	.9658x10 ⁻¹⁵	.2056x10 ⁻¹³	.2063x10 ⁻¹³

Table Ex 4-III

Bottom Product Compositions in Mole Fractions

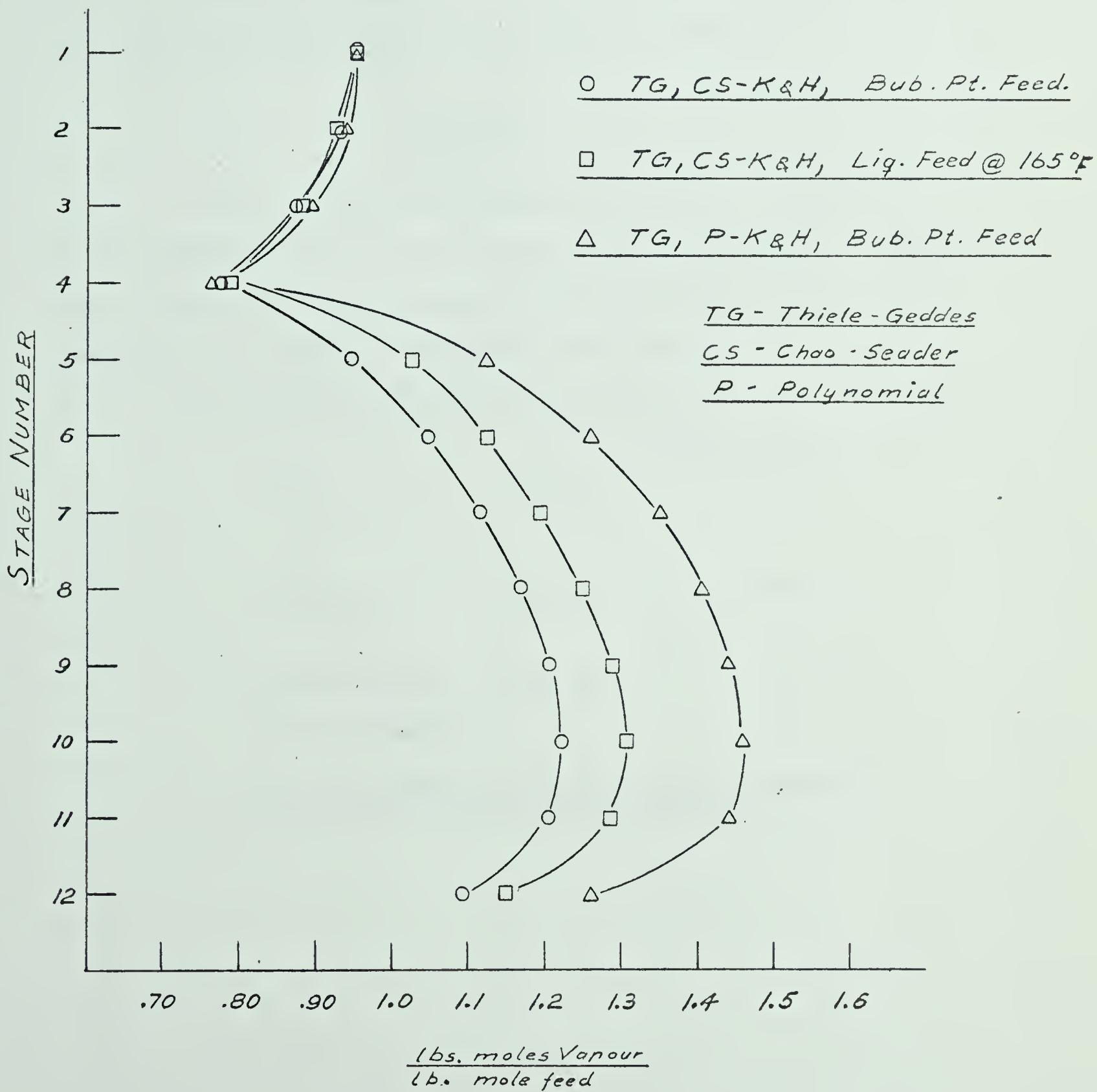
Method Component	4A	4B	4C	4D	4E	4F	4G
CH ₄	.1524x10 ⁻⁸	.1651x10 ⁻⁸	.1550x10 ⁻⁸	.1423x10 ⁻⁸	.1285x10 ⁻⁸	.1654x10 ⁻¹⁰	--
C ₂ H ₆	.4854x10 ⁻⁵	.5124x10 ⁻⁵	.4923x10 ⁻⁵	.4594x10 ⁻⁵	.4232x10 ⁻⁵	.1703x10 ⁻⁵	--
C ₃ H ₆	.1392x10 ⁻²	.1427x10 ⁻²	.1407x10 ⁻²	.1334x10 ⁻²	.1251x10 ⁻²	.4038x10 ⁻³	--
C ₃ H ₈	.7256x10 ⁻²	.7444x10 ⁻²	.7323x10 ⁻²	.6990x10 ⁻²	.6607x10 ⁻²	.2240x10 ⁻²	--
i-C ₄	.4081x10 ⁻¹	.4073x10 ⁻¹	.4080x10 ⁻¹	.4086x10 ⁻¹	.4091x10 ⁻¹	.4029x10 ⁻¹	--
n-C ₄	.2051	.2049	.2051	.2054	.2058	.2114	--
n-C ₅	.2220	.2220	.2220	.2220	.2220	.2222	--
C ₆	.1652	.1652	.1652	.1652	.1652	.1652	--
C ₇	.1316	.1316	.1316	.1316	.1316	.1316	--
C ₈	.1243	.1243	.1243	.1243	.1243	.1243	--
400 N.B.P.	.1023	.1024	.1023	.1023	.1023	.1023	--

Table Ex 4-IV

Vapour Profile for Example 4

Stage	4A	4B	4C	4D	4E	4F	4G
1	.948	.948	.948	.948	.948	.948	.948
2	.924	.924	.920	.925	.926	.931	.933
3	.881	.880	.877	.882	.884	.896	.894
4	.782	.780	.782	.784	.788	.810	.801
5	.949	.945	.948	.977	1.022	1.111	1.107
6	1.044	1.040	1.034	1.074	1.122	1.258	1.260
7	1.110	1.106	1.123	1.141	1.191	1.351	1.365
8	1.162	1.158	1.158	1.144	1.245	1.411	1.440
9	1.201	1.197	1.195	1.233	1.284	1.446	1.484
10	1.220	1.216	1.213	1.251	1.301	1.465	1.490
11	1.202	1.197	1.189	1.230	1.276	1.450	1.433
12	1.089	1.095	1.088	1.111	1.149	1.257	1.233

FIGURE VII
VAPOUR PROFILE COMPARISONS
PROBLEM 4



(5.2) Design Example Problems

To determine the practical use of the Chao-Seader correlation as a source of enthalpy and K-ratio equilibrium data, the following stabilizer design example problems were considered.

Example 5

A stabilizer is to be designed in which it is desired to obtain a specified split on the two n-C₄ and i-C₅ components. The design is based on the short cut method and the short cut predictions are compared to the rigorous Thiele-Geddes calculations.

The specification for the stabilizer are:

$$\left(\frac{d_i}{b_i} \right)_{n-C_4} = 7.60$$

$$\left(\frac{d_i}{b_i} \right)_{i-C_5} = 0.116$$

-column pressure = 345 psia.

-partial condenser

-partially vaporized feed having 0.555 fraction liquid and of the following composition:

<u>Component</u>	<u>Mole Fraction</u>
N ₂	.5426 x 10 ⁻³
H ₂ S	.1150
CO ₂	.1194 x 10 ⁻¹
C ₁	.8410 x 10 ⁻¹
C ₂	.4069 x 10 ⁻¹
C ₃	.7379 x 10 ⁻¹
i-C ₄	.2930 x 10 ⁻¹
n-C ₄	.9333 x 10 ⁻¹
i-C ₅	.5209 x 10 ⁻¹
n-C ₅	.6131 x 10 ⁻¹
C ₆	.1145
C ₇	.1264
C ₈	.6782 x 10 ⁻¹
C ₉	.3961 x 10 ⁻¹
C ₁₀	.8953 x 10 ⁻¹

For this example the short cut was quite conservative compared to the rigorous Thiele-Geddes calculations.

	<u>Short Cut</u>	<u>Thiele-Geddes (N_F = 8)</u>
$(\frac{d_i}{b_i})_{n-C_4}$	7.60	12.5
$(\frac{d_i}{b_i})_{i-C_5}$	0.116	0.0462

Computer object time for both Short Cut and Rigorous calculation = 3 min. 55 sec.

150060

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Table Ex 5-I

OBJECT PROGRAM IS BEING ENTERED INTO STORAGE.

FEED CONDITION

FLASH TEMP= 321.833 F

FRACTION LIQUID= 0.55500000E 00

COMPONENT	MF	FLASH LIQUID	MF	FLASH VAPOUR
NITROGEN		0.81080268E-04		0.11182166E-02
H2S		0.49699359E-01		0.19651337E 00
CO2		0.33119717E-02		0.22694710E-01
METHANE		0.16673159E-01		0.16820272E 00
ETHANE		0.13322704E-01		0.74834049E-01
PROPANE		0.42770937E-01		0.11248470E 00
I-BUTANE		0.22792464E-01		0.37416656E-01
N-BUTANE		0.77259162E-01		0.11336561E 00
I-PENTANE		0.53857353E-01		0.49883390E-01
N-PENTANE		0.65553761E-01		0.56023882E-01
HEXANE		0.14675076E 00		0.74246556E-01
HEPTANE		0.18274532E 00		0.56177866E-01
OCTANE		0.10660941E 00		0.19449299E-01
NONANE		0.65587337E-01		0.72082411E-02
DECANE		0.15298523E 00		0.10380782E-01

Table Ex 5-II

SHORT CUT METHOD

BASIS ONE LB-MOLE FEED

SHORTCUT MINIMUM REFLUX= 2.1616

SHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL REFLUX= 8.3066

SHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATING REFLUX= 15.2346

DISTILLATE TEMP= 149.862 NO OF THEORETICAL PLATES= 16

BOTTOMS TEMP= 468.854 F COLUMN PRESSURE= 345.000 PSIA

REFLUX RATIO= 3.14091 DISTILLATE RATE= 0.44423 FEED PLATE NO= 8

CONDENSER HEAT LOAD= 0.11124641E 05 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.15219902E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
NITROGEN	0.54259359E-03	0.12214259E-02	0.73684724E-12
H2S	0.11502984E 00	0.25893518E 00	0.56878708E-05
CO2	0.11937059E-01	0.26871368E-01	0.23799333E-08
METHANE	0.84102007E-01	0.18932102E 00	0.18076092E-08
ETHANE	0.40694519E-01	0.91606788E-01	0.12525779E-06
PROPANE	0.73792728E-01	0.16588613E 00	0.18207502E-03
I-BUTANE	0.29300054E-01	0.61431654E-01	0.36171291E-02
N-BUTANE	0.93326097E-01	0.18565674E 00	0.19525819E-01
I-PENTANE	0.52088985E-01	0.12214259E-01	0.83961021E-01
N-PENTANE	0.61313076E-01	0.66956085E-02	0.10496905E 00
HEXANE	0.11448725E 00	0.15699002E-03	0.20587190E 00
HEPTANE	0.12642431E 00	0.28276843E-05	0.22747353E 00
OCTANE	0.67824198E-01	0.18708535E-07	0.12203635E 00
NONANE	0.39609332E-01	0.17503272E-09	0.71269237E-01
DECANE	0.89527942E-01	0.76525608E-11	0.16108800E 00

Table Ex 5-III

THIELE GEDDES CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 345.000 PSIA

DISTILLATE TEMP= 146.123

NO OF THEORETICAL PLATES= 16

REFLUX RATIO= 3.14091

DISTILLATE RATE= 0.44423

FEED PLATE NO= 8

STAGE	VAPOUR	LIQUID	TEMPERATURE
1	1.83951	1.53474	202.111
2	1.97897	1.57328	222.727
3	2.01751	1.56150	233.726
4	2.00573	1.52339	242.574
5	1.96762	1.45883	252.103
6	1.90306	1.34198	264.407
7	1.78621	1.65781	283.787
8	1.65704	1.90883	336.363
9	1.35306	2.02336	351.323
10	1.46759	2.08364	361.942
11	1.52787	2.11882	371.555
12	1.56305	2.13529	381.768
13	1.57952	2.13252	394.058
14	1.57675	2.09780	410.391
15	1.54203	2.02750	434.226
16	1.47173	0.55577	470.361

CONDENSER HEAT LOAD= 0.10755995E 05 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.14896920E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
NITROGEN	0.54259359E-03	0.12214222E-02	0.20757247E-11
H2S	0.11502984E 00	0.25893895E 00	0.20417795E-05
CO2	0.11937059E-01	0.26871287E-01	0.11195078E-08
METHANE	0.84102007E-01	0.18932044E 00	0.14462437E-08
ETHANE	0.40694519E-01	0.91606643E-01	0.17935442E-07
PROPANE	0.73792728E-01	0.16605930E 00	0.43258454E-04
I-BUTANE	0.29300054E-01	0.64459787E-01	0.11965750E-02
N-BUTANE	0.93326097E-01	0.19449211E 00	0.12463225E-01
I-PENTANE	0.52088985E-01	0.51877448E-02	0.89577557E-01
N-PENTANE	0.61313076E-01	0.18341588E-02	0.10885509E 00
HEXANE	0.11448725E 00	0.81200844E-05	0.20599141E 00
HEPTANE	0.12642431E 00	0.53346457E-07	0.22747631E 00
OCTANE	0.67824198E-01	0.12479646E-09	0.12203667E 00
NONANE	0.39609332E-01	0.53066324E-12	0.71269417E-01
DECANE	0.89527942E-01	0.11019513E-13	0.16108841E 00

Example 6

A stabilizer similar to example 5 is considered where it is also desired to obtain a specified split on the n-C₄ and i-C₅ components. The design requirements are calculated on the basis of the short cut method and then are compared to the rigorous Bergamini calculations.

The specifications for this stabilizer are:

$$\left(\frac{d_i}{b_i} \right)_{n-C_4} = 5.16$$

$$\left(\frac{d_i}{b_i} \right)_{i-C_5} = 0.0603$$

-column pressure = 280 psia.

-partial condenser

-partially vaporized feed, having .64528 fraction liquid, having the following compositions:

<u>Component</u>	<u>Mole Fraction</u>
N ₂	.7855 x 10 ⁻³
H ₂ S	.9112 x 10 ⁻¹
CO ₂	.1453 x 10 ⁻¹
C ₁	.7188 x 10 ⁻¹
C ₂	.2514 x 10 ⁻¹
C ₃	.5302 x 10 ⁻¹
i-C ₄	.3339 x 10 ⁻¹
n-C ₄	.7502 x 10 ⁻¹
i-C ₅	.6913 x 10 ⁻¹
n-C ₅	.8013 x 10 ⁻¹
C ₆	.1402
C ₇	.1422
C ₈	.7463 x 10 ⁻¹
C ₉	.4203 x 10 ⁻¹
C ₁₀	.8680 x 10 ⁻¹

For this example the short cut method was also conservative compared with the rigorous modified Bergamini calculations.

	<u>Short Cut</u>	<u>Mod. Bergamini ($N_F = 8$)</u>
$(\frac{d_i}{b_i})_{n-C_4}$	5.16	6.64
$(\frac{d_i}{b_i})_{i-C_5}$	0.0603	0.0181

Computer object time for both Short Cut and Rigorous
calculation = 4 min. 54 sec.

150060

Table Ex 6-I

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JECT PROGRAM IS BEING ENTERED INTO STORAGE.

FEED CONDITION

FLASH TEMP= 305.130 F FRACTION LIQUID= 0.64258000E 00

COMPONENT	MF	FLASH LIQUID	MF	FLASH VAPOUR
NITROGEN		0.75538016E-04		0.20621079E-02
H2S		0.39793104E-01		0.18341275E 00
CO2		0.39669332E-02		0.33529188E-01
METHANE		0.14135402E-01		0.17569504E 00
ETHANE		0.83331625E-02		0.55350852E-01
PROPANE		0.31033582E-01		0.92562757E-01
I-BUTANE		0.25989316E-01		0.46684071E-01
N-BUTANE		0.62108804E-01		0.98232735E-01
I-PENTANE		0.70069022E-01		0.67436211E-01
N-PENTANE		0.83734698E-01		0.73636853E-01
HEXANE		0.17091161E 00		0.85037760E-01
HEPTANE		0.19049665E 00		0.55319548E-01
OCTANE		0.10635331E 00		0.17584170E-01
NONANE		0.62086809E-01		0.59595653E-02
DECANE		0.13091207E 00		0.74964221E-02

Table Ex 6-II

SHORT CUT METHOD

BASIS ONE LB-MOLE FEED

SHORTCUT MINIMUM REFLUX= 2.2332

SHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL REFLUX= 7.8895

SHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATING REFLUX= 14.4444

DISTILLATE TEMP= 135.382 NO OF THEORETICAL PLATES= 15

BOTTOMS TEMP= 426.636 F COLUMN PRESSURE= 280.000 PSIA

REFLUX RATIO= 3.29928 DISTILLATE RATE= 0.35543 FEED PLATE NO= 8

CONDENSER HEAT LOAD= 0.98611901E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.13668382E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
NITROGEN	0.78554594E-03	0.22101032E-02	0.15728879E-13
H2S	0.91123329E-01	0.25636472E 00	0.40003616E-05
CO2	0.14532600E-01	0.40886903E-01	0.36244153E-08
METHANE	0.71877454E-01	0.20222444E 00	0.10464971E-08
ETHANE	0.25137470E-01	0.70723165E-01	0.76004779E-07
PROPANE	0.53024352E-01	0.14894263E 00	0.13197852E-03
I-BUTANE	0.33385703E-01	0.85201108E-01	0.48130490E-02
N-BUTANE	0.75019637E-01	0.17680826E 00	0.18890173E-01
I-PENTANE	0.69128043E-01	0.11050516E-01	0.10115383E 00
N-PENTANE	0.80125686E-01	0.54972451E-02	0.12127817E 00
HEXANE	0.14021995E 00	0.89782863E-04	0.21749215E 00
HEPTANE	0.14218381E 00	0.11641031E-05	0.22058782E 00
OCTANE	0.74626864E-01	0.59132812E-08	0.11577847E 00
NONANE	0.42026708E-01	0.43170936E-10	0.65201563E-01
DECANE	0.86802826E-01	0.14235957E-11	0.13466865E 00

Table Ex 6-III

BERGAMINI CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 280.000 PSIA

DISTILLATE TEMP= 131.459

NO OF THEORETICAL PLATES= 15

REFLUX RATIO= 3.29928

DISTILLATE RATE= 0.35543

FEED PLATE NO= 8

STAGE	VAPOUR	LIQUID	TEMPERATURE
1	1.52811	1.28770	187.740
2	1.64313	1.31543	206.022
3	1.67086	1.29709	215.406
4	1.65252	1.26222	223.469
5	1.61765	1.20442	232.885
6	1.55985	1.11155	245.637
7	1.46698	1.31711	265.998
8	1.31513	1.77443	318.427
9	1.12987	1.86035	331.450
10	1.21579	1.90269	340.685
11	1.25812	1.92654	349.363
12	1.28198	1.93317	359.168
13	1.28860	1.91329	372.183
14	1.26872	1.84508	392.351
15	1.20052	0.64457	427.841

CONDENSER HEAT LOAD= 0.95240413E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.13369079E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
NITROGEN	0.78554594E-03	0.22100914E-02	0.77487824E-13
H2S	0.91123329E-01	0.25636618E 00	0.24355673E-05
CO2	0.14532600E-01	0.40886685E-01	0.29562642E-08
METHANE	0.71877454E-01	0.20222335E 00	0.17210124E-08
ETHANE	0.25137470E-01	0.70722881E-01	0.22836665E-07
PROPANE	0.53024352E-01	0.14910239E 00	0.43443123E-04
I-BUTANE	0.33385703E-01	0.90550647E-01	0.18628813E-02
N-BUTANE	0.75019637E-01	0.18341116E 00	0.15248629E-01
I-PENTANE	0.69128043E-01	0.34607292E-02	0.10533938E 00
N-PENTANE	0.80125686E-01	0.10629355E-02	0.12372376E 00
HEXANE	0.14021995E 00	0.29849873E-05	0.21754068E 00
HEPTANE	0.14218381E 00	0.11530399E-07	0.22058913E 00
OCTANE	0.74626864E-01	0.16064304E-10	0.11577883E 00
NONANE	0.42026708E-01	0.42077769E-13	0.65201760E-01
DECANE	0.86802826E-01	0.52417237E-15	0.13466906E 00

Example 7(a)

The required specifications for the stabilizer in this example are:

$$\left(\frac{d_i}{b_i} \right)_{n-C_4} = 5.16$$

$$\left(\frac{d_i}{b_i} \right)_{i-C_5} = 0.060$$

-column pressure = 280 psia.

-partial condenser

-feed partially vaporized entering at 0.82365 fraction liquid and having the following composition:

<u>Component</u>	<u>Mole Fraction</u>
H ₂ S	0.5680 x 10 ⁻¹
CO ₂	0.6518 x 10 ⁻²
C ₁	0.2607 x 10 ⁻¹
C ₂	0.1443 x 10 ⁻¹
C ₃	0.4469 x 10 ⁻¹
i-C ₄	0.3352 x 10 ⁻¹
n-C ₄	0.7821 x 10 ⁻¹
i-C ₅	0.7682 x 10 ⁻¹
n-C ₅	0.9078 x 10 ⁻¹
C ₆	0.1639
C ₇	0.1676
C ₈	0.8799 x 10 ⁻¹
C ₉	0.4981 x 10 ⁻¹
C ₁₀	0.1029

Comparing the short cut to the modified Bergamini's calculational procedure shows that the short cut design is conservative.

	<u>Short Cut</u>	<u>Mod. Bergamini ($N_F = 10$)</u>
$(\frac{d_i}{b_i})_{n-C_4}$	5.16	6.65
$(\frac{d_i}{b_i})_{i-C_5}$	0.060	0.035

Computer object time for both Short Cut and Mod. Bergamini
was - 4 min. 33 sec.

Table Ex 7(a) I

Flash Comparison

P = 280 psia. L/F = 0.82

Compositions (Mole Fraction)

	<u>Feed</u>	<u>CHAO-SEADER</u>		<u>NGSMA (3000#)</u>	
		<u>Liq.</u>	<u>Vap.</u>	<u>Liq.</u>	<u>Vap.</u>
H ₂ S	0.057	0.034	0.162	0.035	0.158
CO ₂	0.006	0.003	0.024	0.002	0.029
C ₁	0.026	0.009	0.107	0.008	0.111
C ₂	0.014	0.007	0.049	0.008	0.045
C ₃	0.045	0.032	0.102	0.032	0.105
i-C ₄	0.033	0.029	0.056	0.028	0.058
n-C ₄	0.078	0.069	0.120	0.070	0.119
i-C ₅	0.077	0.076	0.082	0.075	0.087
n-C ₅	0.091	0.091	0.090	0.090	0.092
C ₆	0.164	0.177	0.103	0.176	0.106
C ₇	0.168	0.189	0.067	0.191	0.058
C ₈	0.088	0.102	0.021	0.103	0.018
C ₉	0.050	0.059	0.007	0.059	0.005
C ₁₀	0.103	0.123	0.009	0.123	0.008

Temp. = 322.5°F.

Temp. = 320°F.

Table Ex 7(a)-II

SHORT CUT METHOD

BASIS ONE LB-MOLE FEED

SHORTCUT MINIMUM REFLUX= 2.3710

SHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL REFLUX= 8.4015

SHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATING REFLUX= 16.1385

DISTILLATE TEMP= 164.022 NO OF THEORETICAL PLATES= 17

BOTTOMS TEMP= 429.435 F COLUMN PRESSURE= 280.000 PSIA

REFLUX RATIO= 3.45662 DISTILLATE RATE= 0.25105 FEED PLATE NO= 10

CONDENSER HEAT LOAD= 0.69109629E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.11768608E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
H2S	0.56797020E-01	0.22623450E 00	0.19873903E-05
CO2	0.65176908E-02	0.25962013E-01	0.10647275E-08
METHANE	0.26070763E-01	0.10384806E 00	0.32573084E-09
ETHANE	0.14432030E-01	0.57487234E-01	0.28914182E-07
PROPANE	0.44692737E-01	0.17775106E 00	0.91910668E-04
I-BUTANE	0.33519553E-01	0.12105652E 00	0.41773733E-02
N-BUTANE	0.78212289E-01	0.26097946E 00	0.16949177E-01
I-PENTANE	0.76815642E-01	0.17385279E-01	0.96736554E-01
N-PENTANE	0.90782122E-01	0.91351635E-02	0.11814998E 00
HEXANE	0.16387337E 00	0.15866995E-03	0.21875013E 00
HEPTANE	0.16759776E 00	0.20792291E-05	0.22377543E 00
OCTANE	0.87988825E-01	0.10650160E-07	0.11748246E 00
NONANE	0.49813780E-01	0.76999001E-10	0.66511237E-01
DECANE	0.10288641E 00	0.24804644E-11	0.13737368E 00

Table Ex 7(a)-III

BERGAMINI CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 280.000 PSIA

DISTILLATE TEMP= 160.569

NO OF THEORETICAL PLATES= 17

REFLUX RATIO= 3.45662 DISTILLATE RATE= 0.25105 FEED PLATE NO= 10

STAGE	VAPOUR	LIQUID	TEMPERATURE
1	1.11882	0.92564	201.091
2	1.17669	0.93213	215.751
3	1.18318	0.91918	224.508
4	1.17023	0.89934	232.333
5	1.15039	0.87671	240.573
6	1.12775	0.85161	249.518
7	1.10266	0.81509	259.482
8	1.06614	0.75011	271.839
9	1.00116	0.83145	291.059
10	0.90606	1.64102	337.792
11	0.89207	1.72908	345.947
12	0.98012	1.77163	356.361
13	1.02268	1.79417	363.247
14	1.04522	1.82102	371.019
15	1.07207	1.80961	381.543
16	1.06065	1.78393	398.583
17	1.03498	0.74895	430.316

CONDENSER HEAT LOAD= 0.67250944E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.11617508E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
H2S	0.56797020E-01	0.22622108E 00	0.61849520E-05
CO2	0.65176908E-02	0.25961896E-01	0.61654118E-08
METHANE	0.26070763E-01	0.10384765E 00	0.36350340E-08
ETHANE	0.14432030E-01	0.57486963E-01	0.44408028E-07
PROPANE	0.44692737E-01	0.17773915E 00	0.95666100E-04
I-BUTANE	0.33519553E-01	0.12612836E 00	0.24771409E-02
N-BUTANE	0.78212289E-01	0.27080781E 00	0.13654397E-01
I-PENTANE	0.76815642E-01	0.90632171E-02	0.99526213E-01
N-PENTANE	0.90782122E-01	0.27399724E-02	0.12029380E 00
HEXANE	0.16387337E 00	0.39102368E-05	0.21880231E 00
HEPTANE	0.16759776E 00	0.66178185E-08	0.22377643E 00
OCTANE	0.87988825E-01	0.37443540E-11	0.11748262E 00
NONANE	0.49813780E-01	0.41731828E-14	0.66511328E-01
DECANE	0.10288641E 00	0.22795731E-16	0.13737387E 00

Example 7(b)

A stabilizer is considered having the same feed as example 7(a), and having the following specifications:

- partial condenser
- column pressure of 280 psia.
- condenser temperature is specified at 110°F.
- the composition X_{C_3} in the bottoms is to be ≤ 0.001 mole fraction.

To use the short cut program without change, the splits on C_3 and $i-C_4$ were estimated by hand calculations. These were then used as specifications in the short cut program.

The calculated short cut results are compared to the Thiele-Geddes below:

	<u>Short Cut</u>	<u>Thiele-Geddes ($N_F = 10$)</u>
T_C	110.2	111.0
$(X_B)_{C_3}$	0.0056	0.02741

Table IX '7(b)-I

SHORT CUT METHOD

BASIS ONE LB-MOLE FEED

SHORTCUT MINIMUM REFLUX= 2.0967

SHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL REFLUX= 8.1042

SHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATING REFLUX= 14.8886

DISTILLATE TEMP= 110.175 NO OF THEORETICAL PLATES= 15

BOTTOMS TEMP= 401.786 F COLUMN PRESSURE= 280.000 PSIA

REFLUX RATIO= 3.34027 DISTILLATE RATE= 0.17588 FEED PLATE NO= 10

CONDENSER HEAT LOAD= 0.44755486E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.78485542E 04 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
H2S	0.56797020E-01	0.32284954E 00	0.17094035E-04
CO2	0.65176908E-02	0.37057444E-01	0.11766232E-07
METHANE	0.26070763E-01	0.14822999E 00	0.16072590E-08
ETHANE	0.14432030E-01	0.82054503E-01	0.29632593E-06
PROPANE	0.44692737E-01	0.25146161E 00	0.56490513E-03
I-BUTANE	0.33519553E-01	0.79408927E-01	0.23726016E-01
N-BUTANE	0.78212289E-01	0.76825471E-01	0.78508257E-01
I-PENTANE	0.76815642E-01	0.14461081E-02	0.92900720E-01
N-PENTANE	0.90782122E-01	0.65809271E-03	0.11001605E 00
HEXANE	0.16387337E 00	0.82667050E-05	0.19884484E 00
HEPTANE	0.16759776E 00	0.85531527E-07	0.20336582E 00
OCTANE	0.87988825E-01	0.33412562E-09	0.10676707E 00
NONANE	0.49813780E-01	0.19677039E-11	0.60444848E-01
DECANE	0.10288641E 00	0.52818508E-13	0.12484403E 00

Table Ex 7(5)-II

THIELE GEDDES CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 280.000 PSIA

DISTILLATE TEMP= 110.999

NO OF THEORETICAL PLATES= 15

REFLUX RATIO= 3.34027 DISTILLATE RATE= 0.17588 FEED PLATE NO= 10

STAGE	VAPOUR	LIQUID	TEMPERATURE
1	0.76337	0.61824	162.547
2	0.79412	0.63293	183.961
3	0.80881	0.63641	194.113
4	0.81229	0.63330	200.003
5	0.80918	0.62457	204.620
6	0.80045	0.60739	209.731
7	0.78327	0.57465	217.222
8	0.75053	0.50934	230.395
9	0.68522	0.61009	257.049
10	0.60953	1.32458	323.748
11	0.50046	1.38331	332.438
12	0.55920	1.42258	340.154
13	0.59846	1.44912	349.877
14	0.62500	1.45375	366.382
15	0.62963	0.82412	401.122

CONDENSER HEAT LOAD= 0.44370146E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.77695786E 04 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

COMPONENT	FEED	DISTILLATE	BOTTOMS
H2S	0.56797020E-01	0.32133305E 00	0.32697618E-03
CO2	0.65176908E-02	0.37044800E-01	0.11221600E-05
METHANE	0.26070763E-01	0.14819678E 00	0.73495333E-06
ETHANE	0.14432030E-01	0.82003100E-01	0.77511049E-05
PROPANE	0.44692737E-01	0.24120245E 00	0.27441526E-02
I-BUTANE	0.33519553E-01	0.92310544E-01	0.20969543E-01
N-BUTANE	0.78212289E-01	0.77641704E-01	0.78334093E-01
I-PENTANE	0.76815642E-01	0.21600694E-03	0.93167234E-01
N-PENTANE	0.90782122E-01	0.51554269E-04	0.11015022E 00
HEXANE	0.16387337E 00	0.46392929E-07	0.19885513E 00
HEPTANE	0.16759776E 00	0.46873702E-10	0.20337457E 00
OCTANE	0.87988825E-01	0.13688578E-13	0.10677165E 00
NONANE	0.49813780E-01	0.89999946E-17	0.60447442E-01
DECANE	0.10288641E 00	0.29813285E-19	0.12484939E 00

Since the short cut is specified at optimum feed location, the feed stage was varied in the rigorous calculations to see if the specification could be met.

Table Ex 7(b) - III

Changing Feed Stage Location

N	=	15	
D	=	17588	
R	=	3.34027	
N_F	7	5	4
$(X_B)_{C_3}$	0.0018	0.0011	0.0009
T_C	111	112	114
T_R	401	402	401
Q_C	4476	4558	4661
Q_R	7832	7921	8024

The specifications could not be met by merely changing the feed stage, however, they could be satisfied using:

N	D	R	N_F	Computer Object Time
14	0.1737	3.7	4	3 min. 12 sec.
20	0.1745	2.8	5	5 min. 21 sec.

(6) Discussion of the Chao-Seader Correlation

(6.1) Comparison of the Chao-Seader Correlation K-ratios to Experimental Data

The agreement of the Chao-Seader correlation K-ratio data predictions for hydrocarbon systems, including aromatics and naphthenes, with experimental values, reported by Chao and Seader⁽⁹⁾, Shelton and Wood⁽⁵⁸⁾, and Cavett⁽⁸⁾ is well within the accepted deviation of standard published paraffin equilibrium values. Some of the reported deviations of published data are tabulated in Table III. The accuracy is reported as the average percent absolute arithmetic deviation relative to experimental values.

Table III

<u>Method of K-ratio Calculation</u>	<u>Number of Points Considered</u>	<u>Average Deviation Percent</u>
NGSMA*	156	8.0
Rzasa*	156	9.1
Winn*	156	10.1
Meyers and Lenoir ⁽³⁹⁾	156	7.3
Hadden and Grayson ⁽²³⁾	1,964	6.8, 6.2, 7.1 (for the three correlations)
Chao and Seader ⁽⁹⁾	2,692	8.7
Cavett ⁽⁸⁾ {Chao-Seader Black eqn.}	472	4.8
(Chao-Seader Redlich and Kwong eqn.)	615	5.2

* Comparison made by Meyers and Lenoir.

Multicomponent hydrocarbon mixtures often contain dissolved nonhydrocarbon gaseous components. Sets of special Chao-Seader constants for carbon dioxide, hydrogen sulfide and nitrogen have been calculated by Erbar and Edmister⁽¹⁸⁾, who claim reasonable K-ratio predictions for these components. Only scant information, due to lack of reliable data, is available on the accuracy and dependability of these K-ratio predictions in natural gas systems. Comparisons of the predicted Chao-Seader K-ratios to experimental data were, therefore, made on several sweet and sour hydrocarbon systems studied by Saxena⁽⁵⁴⁾.

Bubble and Dew point calculations were performed on the systems $\text{CO}_2\text{-C}_1\text{-n-C}_4$ and $\text{H}_2\text{S-C}_1\text{-n-C}_4$, and these were compared to the experimental data of Saxena, which ranged from -20 to 100 °F. in temperature and 400 to 1200 psia. in pressure. Bubble point calculations were of special interest because they were used in the rigorous Thiele-Geddes calculational procedure. Three different sets of constants for the liquid fugacity coefficients' equations were investigated. These were:

- (a) the Grayson Streed set of constants, appendix III table II
- (b) the Chao-Seader constants, appendix III table I
- (c) the Chao-Seader set of generalized constants combined with the special constants for carbon dioxide and hydrogen sulfide proposed by Erbar and Edmister, appendix III table III.

Little difference in the accuracy of data prediction was observed between the three sets of constants. The special constants of comparison (c) gave only slightly better values than the generalized

constants in (a) and (b) for carbon dioxide and hydrogen sulfide. Sample comparisons on the three sets of constants are presented in tabular form in appendix II.

For mixtures containing more than 0.05 mole fraction of any one component and less than 30 mole percent hydrogen sulfide and carbon dioxide in the liquid phase, the calculated bubble and dew point temperatures were usually within 15°F. of experimental. The dew point temperatures, as expected, compared consistently better to experimental values than did the bubble point temperatures. Differences of up to 30°F. between predicted and experimental temperatures were encountered in bubble and dew point calculations for the -20°F. temperature data and also for the higher pressure data of 1200 psia., at high concentrations of hydrogen sulfide and carbon dioxide. An increase in the differences between experimental and predicted K-ratios and temperatures was observed for mixtures approaching binaries.

A constant temperature flash K-ratio comparison has been recently made by Saxena⁽⁵⁴⁾ on the systems $\text{CO}_2\text{-C}_1\text{-n-C}_4$, $\text{H}_2\text{S-C}_1\text{-n-C}_4$ and $\text{C}_1\text{-n-C}_4\text{-n-C}_6$. Absolute standard deviations of 20-40 percent from experimental data were obtained for these systems where the carbon dioxide and hydrogen sulfide concentration in the liquid phase was less than 30 mole percent. These deviations appear to be of about the same magnitude as those reported by Erbar and Edmister⁽¹⁸⁾ for carbon dioxide and hydrogen sulfide.

The deviations of the above ternary systems are about four times those reported for hydrocarbon systems, table III, for the Chao-

Seader correlation Better K-ratio predictions have been reported by Shelton and Wood⁽⁵⁸⁾ for systems where a large number of hydrocarbon components are present and if the concentration of the gaseous components, such as hydrogen sulfide and carbon dioxide is low. A comparison of the Chao-Seader K-ratios to N.G.S.M.A. values is presented in table Ex-7(a)-I for such a system.

In summary, the Chao-Seader correlation, although some improvement in its accuracy is desired when dissolved non hydrocarbon gaseous components are present in the mixture, is acceptable for predicting vapour-liquid equilibrium data in hydrocarbon mixtures. At present it appears to be one of the best sources of data available for computer use for both hydrocarbon and natural gas systems.

(6.2) Theoretical Limitations of the Chao-Seader Correlation

Since the Chao-Seader K-ratio is defined as:

$$K_i = \frac{\gamma_i v_i^\circ}{\phi_i}$$

the K-ratio thus calculated is subject to the various limitations in the calculation of v_i° , γ_i and ϕ_i .

The pure component liquid fugacity coefficient v_i° is primarily responsible for reflecting the effect of component identity, temperature and pressure. Actually, it is the pure component ideal K-ratio, which requires the ideal gas and ideal solution assumptions. The accuracy of v_i° depends on the curvefit of the experimental data in terms of P_R , T_R and the acentric factor ω . The acentric factor which is used, in the Chao-Seader correlation is not derived according to Pitzer's definition but is determined empirically as a parameter for the best fitting of the vapour pressure curve by the liquid fugacity coefficient equations.

The gas phase is quite adequately handled by the Redlich and Kwong equation of state, from which the vapour fugacity coefficient expression was derived by Redlich and Kwong⁽⁴⁹⁾.

Both v_i° and ϕ_i are limited only by the accuracy with which they represent the available data and this accuracy may be improved by using more complicated expressions. Hence they are not limited by theoretical assumptions but merely by the experimental data and the mathematical expressions representing them.

Scatchard⁽⁵⁶⁾ introduced the concept of expressing the non-ideality of a liquid mixture in terms of the excess Gibbs free energy

$$\Delta F_i^m$$

$$\ln \gamma_i = \frac{\Delta F_i^m}{R^*T} \quad (6.2-1)$$

The excess Gibbs free energy ΔF_i^m consists of two parts: an excess enthalpy term and an excess entropy term as shown by equation 3.6-5. The assumption of ΔF_i^m equal to zero leads to the equations for ideal solution. The next simplest assumption is to set either ΔH_i^m or $T\Delta S_i^m$ equal to zero. The condition of $\Delta H_i^m = 0$ leads to the concept of "athermal" solutions developed by Flory⁽²⁰⁾ and Huggins⁽²⁷⁾. The Wilson equation^(67,44) is a semi-empirical extension of this approach. It claims to predict multicomponent equilibrium data from binary data for hydrocarbons as well as polar compounds.

An alternate approach is to assume $\Delta S_i^m = 0$. This leads to the concept of "regular" solutions. Van Laar, Hildebrand and Scatchard have taken this approach. The Chao-Seader correlation is also based on this assumption of "regular" solutions. This theory of solution describes well the multicomponent hydrocarbon equilibrium behaviour and, to a limited degree, the solution of various non-hydrocarbon gases in hydrocarbon systems. The liquid activity coefficient γ_i assuming $\Delta S_i^m = 0$ is obtained from equation 3.6-10 which is also described below:

$$\ln \gamma_i = \frac{V_i^* (\delta_i - \bar{\delta}_m)^2}{R^*T}$$

Chao and Seader found that the solubility parameter and the component molar volumes could be taken as constants for the range of the correlation although they were actually slightly temperature dependent. Furthermore, this simplification assumes that the excess free energy is independent of temperature as required by the vanishing of the excess entropy in the "regular" solution assumption.

Because of the squared term in the above equation, $\log \gamma_i$ must always be greater than zero, and hence γ_i must always be greater than unity. Also, the solubility parameters γ_i and the component partial molar volumes V_i^* of the non hydrocarbon gaseous components are not significantly different from those of the light hydrocarbons. As a result the predicted γ_i will be ≥ 1 and close to unity for natural gas systems.

Large variation in K-ratios in nonideal systems, such as $\text{CO}_2\text{-H}_2\text{S-C}_1$, has been attributed to variations of γ_i . Robinson, et. al. (51,52) obtained $(\gamma_i)_{\text{CO}_2}$ as high as 10.1 at 40°F. , 400 psia., and $(\gamma_i)_{\text{C}_1}$ as low as 0.168 at 160°F. , 1600 psia., for the system $\text{CO}_2\text{-H}_2\text{S-C}_1$. These large variations in γ_i cannot be accounted for by the regular solution theory, especially in the latter case where γ_i is less than one. In cases like this the Chao-Seader correlation fails.

(6.3) Practical Limitations of the Chao-Seader Correlation

The Chao-Seader correlation based on the assumption of "regular" solutions, $\Delta S_i^m = 0$, applies to hydrocarbons of various molecular types including paraffins, olefins, aromatics and naphthenes. Chao and Seader⁽⁹⁾ claim an overall average deviation in K-ratios of 8.7 percent for these components from experimental values. The vapour-liquid equilibrium K-ratios for nonhydrocarbon gases in solution such as carbon dioxide, nitrogen, hydrogen sulfide, hydrogen, carbon monoxide and oxygen may also be predicted provided that their concentration in the liquid phase is below 30 mole percent. According to Chao and Seader the correlation is subject to the following limitations:

Table IV

Chao-Seader Correlation Limitations
for Hydrocarbons (except Methane)

- Reduced temperature 0.5 to 1.3 based on the pure component critical temperature.
- Pressure up to 2000 psia., but not to exceed 0.8 of the critical pressure of the system.

for Methane and Gases

- Temperature from -100°F. to about 0.93 in the pseudoreduced temperature of the equilibrium liquid mixture but not to exceed 500°F. The pseudoreduced temperature is based on the molar average of the critical temperatures of the components.
- Pressure up to 8000 psia.
- Concentration up to 20 mole percent of dissolved gases in the liquid.

(7) Discussion of Problems

(7.1) Comparison of Literature Example Problems

(a) Reproducibility of Results

The Thiele-Geddes and the modified Bergamini's method rigorous calculations for example problems one to four agreed generally to at least three digits. The slight variations in results can be attributed to the convergence tolerances. With the convergence restrictions described in section 5.5 the solutions were stable and converged rapidly for the four example problems, as illustrated in figure VI.

Differences in the calculations between the two methods lie in the grouping of the column equations. The Thiele-Geddes procedure groups the equations by type, hence the stage compositions are solved for the whole column followed by the temperature and the rate profiles. In the modified Bergamini's calculational procedure the equations are solved for each individual stage. As a result the stage compositions are immediately available and can be corrected as the stage temperature is corrected. Since the K-ratios are composition dependent, it was expected that this method would converge more rapidly. However, for the programs developed little if any computational time was saved.

For the problems calculated with the Chao-Seader data close convergence tolerances could be specified. $\text{Abs. (D-Dspec)} \leq 1.0 \times 10^{-4}$ and $\text{Abs. (1-theta)} \leq 1.0 \times 10^{-3}$ were found to be the optimum for giving sufficiently accurate results and yet a reasonable computer time for convergence. When the specifications for these convergence criteria were set to 1.0×10^{-6} the solution in some cases

would oscillate and never reach these convergence specifications. For some of the polynomial data calculations the convergence criteria tolerances had to be relaxed to: $\text{Abs. (D-Dspec)} \leq 5.0 \times 10^{-4}$ and $\text{Abs. (1-theta)} \leq 2.5 \times 10^{-3}$.

(b) Data Variation

Stocking, Erbar and Maddox⁽⁶¹⁾ point out that substantial differences in distillation column rigorously calculated results occur due to variation of K-ratio and enthalpy data sources. Often all the data required cannot be obtained from one source and the resulting combination of data sources may lead to inconsistencies. The need for a general correlation which predicts K-ratio and enthalpy data consistent with the equilibrium data for a wide range of temperature, pressure and composition is, therefore, apparent.

A comparison of one such correlation proposed by Chao and Seader to a variety of conventional data in example problems published by Holland and Stocking, et. al., was made for example problems one to four. These comparisons show that the Chao-Seader data falls well within the range of results for conventional data as found by Stocking, et. al.

(c) Range of Components in the Feed

In example problem one the temperatures, compositions, heat loads and flow rates for the Chao-Seader data are in close agreement with the results calculated using the polynomial data from Holland K-ratios from Scheibel and Jenney⁽⁵⁷⁾ and enthalpy data from Maxwell⁽³⁷⁾. This is probably due to the narrow range five component feed, C_3 to

n-C₅. The convergence pressure, which exhibits the effect of composition, does not vary over a wide range throughout the column and hence the effect of composition on the equilibrium data may be relatively unimportant.

For example problem two, a seven component feed C₂H₆ to C₇H₁₆ is specified. Differences between the Chao-Seader data results and those presented by Stocking, et. al., for N.G.S.M.A. K's and Kellog enthalpies and Winn K's and Kellog enthalpies, are due to the component "propane". High concentrations of propane occur in the rectifying section, i.e., 95% plus in the distillate. The temperature profile in the top section of the column is, therefore, largely dependent on the stage compositions and on the equilibrium data of propane. A distillate temperature of 110.7°F. was calculated from the Chao-Seader data compared to 101.2°F. for the N.G.S.M.A. K's.

A bubble point feed having eleven components ranging from CH₄ to a 400 N.B.P. cut hypothetical component was calculated for example problem four. The bubble point temperature calculation is extremely sensitive to the equilibrium data, especially for a wide boiling feed. Therefore, this type of specification is not particularly a good one for this problem. A feed temperature of 181.2°F. was obtained for the Chao-Seader data as compared to 164.8°F. calculated from the data of Holland, K-ratios from Hadden⁽²⁵⁾. The flash calculations on the other hand agree quite well as shown in the feed for example problem 7, table Ex-7(a)-I. The Chao-Seader data constant L/F = 0.82 flash, temperature was 322.5°F. compared to 320°F. obtained for the N.G.S.M.A. data.

(d) Temperature Profile

The temperature profile calculated by the bubble point method is largely dependent on the stream compositions and, therefore, on the equilibrium data. In example one, because of the narrow component range feed, the temperature profiles were in good agreement for all combinations of K-ratio and enthalpy data studied. A variation in the temperature profile was noticeable for the change in K-ratio data source for calculations 1E (Chao-Seader data) and 1F (polynomial data). The change in temperature profile due to different enthalpy data source for calculations 1B (Chao-Seader) and 1E (polynomial) was negligible.

Up to 20 percent variation in the temperature profiles, compared to N.G.S.M.A. K's and Kellog H-values, was obtained by Stocking, et. al.⁽⁶¹⁾ for example problem two, using various sources of K-ratio data. The variation due to change in enthalpy source for this problem was only 10 percent. According to these variations the temperature profile calculated from the Chao-Seader data is in fair agreement with the conventional data sources, as it varied only 10 percent from the N.G.S.M.A. data. The main differences in the temperature profile from the calculations made by Stocking, et. al. occurred in the stripping section of the column, while the rectifying section profiles were almost identical. However, with the Chao-Seader data, $T_D=110.7^{\circ}\text{F.}$, the difference in the temperature profiles compared to the N.G.S.M.A. data $T_D=101.2^{\circ}\text{F.}$, occurred in the rectifying section of the column. The almost identical results, in the rectifying section, obtained by Stocking, et. al., is probably the result of a common source of K-ratio data for propane for some of the charts. This component reaches a concentration of 95 percent in the

rectifying section and hence the temperature profile is very sensitive to its K-ratio data.

In example problem three, where a split feed and a partial condenser were considered, the temperature profiles compared well for the Chao-Seader data, $T_D = 129.9^\circ\text{F.}$, $T_B = 339.4^\circ\text{F.}$, and the polynomial data, $T_D = 127.0^\circ\text{F.}$, $T_B = 346.2^\circ\text{F.}$ With the specification of a bubble point feed; for example problem four, a slightly poorer temperature comparison, $T_D = 113.0^\circ\text{F.}$, $T_B = 366.6^\circ\text{F.}$, for polynomial data, was obtained. For all the problems considered the temperature profiles for the Chao-Seader data agreed within 10 percent with those calculated from polynomial data.

(e) Vapour Liquid Flow Rate Profiles

Vapour-liquid flow rate profiles are sensitive to both K-ratio and enthalpy data. In particular the temperature profile, which is dependent on the stage compositions and hence on the K-ratio data, has the controlling influence on the vapour profile. This temperature influence was exhibited in the computer column calculations where the stability of the vapour profile and, therefore, the stability of the solution was directly dependent on the permissible amount of variation in the temperature profile for each iterative column calculation. Only slight variations occur in example problem one vapour profiles when using Chao-Seader or polynomial K-ratio and enthalpy data sources, because of the close comparison of both the stage compositions and temperature profiles.

The feed condition specification has a significant effect on the vapour profile as demonstrated in example problem four. For the

specification of a bubble point feed, the vapour loading calculated for the Chao-Seader data, $T_F = 181.2^\circ\text{F.}$, was 20 percent less than that for polynomial data from Holland, $T_F = 164.8^\circ\text{F.}$ When the feed was specified to enter at a temperature of 165°F. , the difference in the vapour profiles was reduced to 12 percent.

Stocking, et. al., obtained a 10 percent variation, compared to N.G.S.M.A. K's and Kellog enthalpies, in vapour loading for conventional enthalpy data sources and 20 percent for K-ratio data sources. The Chao-Seader data calculated vapour profiles compared reasonably well to the polynomial data ones for example problems two, three and four, and the variations were comparable to those of Stocking, et. al.

This 20 percent variation in vapour loading for different data could prove to be a serious factor if the column was to be designed on the conservative side.

(f) Condenser-Reboiler Heat Loads

Condenser-reboiler heat loads are dependent on both equilibrium and enthalpy data sources. Stocking showed that for example problem two large variations up to 40 percent from N.G.S.M.A. data are possible for reboiler heat loads. Usually the agreement is within 20 percent and is directly dependent on the degree of variation in the vapour-liquid profiles.

For the four problems studied the Chao-Seader data calculated heat loads compared within 10 percent to polynomial data heat loads as shown in table V.

Table V

Condenser-Reboiler Heat Loads

Example Problem 2

K-ratio-Enthalpy Data Source

		<u>Chao-Seader</u>	<u>NGSMA-Kellog</u>	<u>Winn-Kellog</u>	<u>Polynomial from Holland</u>
BTU/lb mole	Q_C	6,332	5,770	7,930	--
feed					
"	" Q_R	8,324	7,500	7,760	--

Example Problem 3

"	" Q_C	8,771	--	--	9,268
"	" Q_R	5,661	--	--	5,670

Example Problem 4

"	" Q_C	3,949	--	--	3,902
"	" Q_R	11,610	--	--	13,290

(7.2) Short Cut Design Compared to the Rigorous Solution

The Fenske-Underwood-Erbar and Maddox short cut, a method commonly used for hand design calculations, was programmed with the Chao-Seader correlation as the data source for the specified split on two components. The results calculated by this method were always conservative compared to the rigorous method, for the example design problems five to seven(a).

The feed stage location for the short cut method is assumed to be at the optimum location. Therefore, some criterion must be used to determine where the feed stage is to be located. The choice of the feed stage as that stage whose temperature is closest to the feed temperature on the basis of a linear temperature profile was not a particularly good one. A better way of estimating the optimum feed stage location would provide a better basis for comparison of the short cut and rigorous calculations. Although the short cut design satisfied the specifications for example problem seven(b), the specifications could not be met by rigorous calculations based on the short cut design by merely changing the feed stage location. The rigorous design could, however, be readily obtained by trial and error.

(8) Conclusions

The Chao-Seader correlation is limited to hydrocarbon systems and is applicable only where the liquid activity coefficients are \leq one. The Chao-Seader calculated K-ratio absolute arithmetic average deviation from experimental data from literature sources ranged from 8.7 to 4.8 percent for hydrocarbon systems. This is well within the reported range of polynomial data. When nonhydrocarbon components are present up to 40 percent deviation from experimental K-ratios is possible for natural gas systems. Poor K-ratios are also predicted in binary systems. However, in multicomponent hydrocarbon systems the Chao-Seader data predictions are accurate enough to be useful for design calculations.

The time requirement for the Chao-Seader data calculated problems was only three times that required for polynomial data. The versatility of the general correlation, such as the Chao-Seader, in handling a variety of problems at various conditions is well worth the additional computer time requirement.

There was little computational time difference between the Thiele-Geddes and the modified Bergamini calculational procedure computer programs. The problems compared to literature polynomial data calculated results compared to within 20 percent in product compositions, heat loads, temperature profiles and vapour-liquid profiles. This is within the variation that Stocking, et. al.⁽⁶¹⁾ found for conventional polynomial data for example problem 2.

The time requirement is reasonable for rigorous column design using these programs. The advantages of the rigorous calculations is that the optimum feed stage location can be calculated and the vapour-liquid loadings throughout the column can be obtained. This in turn can provide a smaller margin of error, and hence the column can be designed with closer tolerances.

Nomenclature

A	-	Chao-Seader liquid fugacity equations constants.
A	-	Redlich and Kwong equation of state constant.
A_i	-	Redlich and Kwong equation of state component "i" constant.
$A_{i,n}$	-	absorption factor.
B	-	bottom product rate.
B	-	Redlich and Kwong equation of state constant.
B_i	-	Redlich and Kwong equation of state component "i" constant.
b_i	-	bottom product component molar flow rate (lb moles/lb mole feed).
D	-	distillate rate (lb moles/lb mole feed).
d_i	-	distillate product component molar flow rate.
F	-	feed rate (1 lb mole basis).
f_{il}	-	fugacity of component "i" in the liquid phase.
f_i°	-	liquid fugacity of pure component "i".
$f_{i,n}$	-	component molar feed rate.
f_{iv}	-	fugacity of component "i" in the vapour phase.
F_{vap}	-	vapour fraction in the feed when a partially vapourized feed is considered.
h_f^*	-	feed molar enthalpy.
\bar{H}_f	-	molar enthalpy of the vapour entering the stage above the feed.
H_i^*	-	partial molar liquid enthalpy of component "i" in ideal liquid solution.
H_i°	-	component molar enthalpy of component "i" as an ideal gas.
$\bar{h}_{i,n}$	-	partial molar component enthalpy of the liquid leaving stage "n".

H_n	-	molar enthalpy of a vapour stream.
h_n	-	molar enthalpy of a liquid stream.
$K_{i,n}$	-	equilibrium K-ratio of component "i" at stage "n".
\bar{L}_f	-	total liquid entering the feed stage.
$\bar{l}_{i,f}$	-	liquid component molar flow rate entering the feed stage.
l_{if}	-	component molar flow rate in the liquid phase of a partially vapourized feed.
$l_{i,n}$	-	liquid component molar flow rate leaving stage "n".
L_n	-	liquid flow rate leaving stage "n".
N	-	number of theoretical stages in the distillation column.
N_F	-	feed stage.
N_m	-	minimum number of theoretical stages.
P	-	column pressure (psia.)
P_C	-	critical pressure (psia.)
P_i	-	partial pressure of pure component "i" (psia.)
P_R	-	reduced pressure
Q_C	-	condenser heat load (BTU/lb mole feed).
q_n	-	stage heat leak (assumed = 0 for the distillation column model).
Q_R	-	reboiler heat load (BTU/lb mole feed)
R	-	reflux ratio.
R_m	-	minimum reflux ratio.
R_o	-	operating reflux ratio.
R^*	-	universal gas constant
$S_{i,m}$	-	stripping factor.
T_C	-	critical temperature ($^{\circ}$ R).

T_n	-	stage temperature ($^{\circ}\text{R}$).
T_R	-	reduced temperature.
$\bar{V}_{i,f}$	-	vapour component molar flow rate entering the stage above the feed.
v_{if}	-	component molar flow rate in the vapour phase of a partially vapourized feed.
$v_{i,n}$	-	vapour component molar flow rate at stage "n".
V_i^*	-	molar volume of component "i".
\bar{V}_f	-	vapour flow rate entering the stage above the feed.
V_n	-	vapour flow rate at stage "n"
X_{if}	-	overall feed compositions (mole fraction).
$x_{i,n}$	-	liquid stage composition (mole fraction).
$y_{i,n}$	-	vapour stage composition (mole fraction).
Z	-	compressibility factor.
α_i	-	relative volatility of component "i".
γ_i	-	liquid activity coefficient of component "i".
∂	-	differential operator.
δ_i	-	solubility parameter of component "i" (cal/ml) ^{1/2}
$\bar{\delta}_m$	-	weighted average solubility parameter defined by equation (3.6-10).
ΔE	-	energy of vaporization, (cal/gm mole).
ΔF_i^m	-	excess partial molal free energy of mixing for component "i" (cal/gm mole).
ΔH_i^m	-	partial molal heat of mixing for component "i" (cal/gm mole)
ΔS_i^m	-	excess partial molar entropy of mixing for component "i" ($\text{cal/gm mole } ^{\circ}\text{K}$).
θ	-	theta root of the Underwood equations.

θ	-	theta convergence.
λ_i	-	latent heat of vapourization for component "i" (cal/gm mole).
v_i^s	-	component liquid fugacity coefficient
Σ	-	summation
ϕ_i	-	vapour fugacity coefficient
ψ_{in}	-	slope of $\ln (K_{i,n})$ vs. T_n as defined by equation 3.3-14.
χ	-	ratio of the dew point to the bubble point as defined in equations 3.3-11 and 3.3-12.
ω_i	-	acentric factor for component "i".

Subscripts

a	-	assumed value.
B	-	bottoms.
c	-	number of components
ca	-	calculated value.
co	-	corrected value.
D	-	distillate.
f	-	feed stage.
hk	-	heavy key component.
i	-	component.
lk	-	light key component
m	-	stage number in the stripping section of the column.
n	-	stage number.
o	-	column reflux liquid stream.
T_n	-	calculated at temperature.

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* This literature was not read by the author.

APPENDIX I

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Description Of Contents

The design of stabilizers by the trial and error method, using the rigorous Thiele-Geddes or modified Bergamini's Computational procedure, requires some knowledge of the trends in column behaviour due to changes of the independent variables. Five independent variables, (i) the number of theoretical stages, (ii) the feed stage location, (iii) the reflux ratio, (iv) the distillate rate and (v) the column pressure, were studied for example problem 7(b). The results obtained are tabulated in this appendix.

TABLE I-1
 VARYING THE NUMBER OF THEORETICAL STAGES

1(a)		Fixed Independent Variables							
		Column Pressure	=	280 psia					
		Distillate Rate	=	0.180 lb. mols/lb mole feed					
		Reflux Ratio	=	3.500					
1(b)		Column Dependent Variables							
N _T	N _F	OF		i-C ₄ bi/di	n-C ₄ bi/di	BTU lb. mole feed		Q _R	X _{B-C3}
		T _D	C ₃ bi/di			Q _C			
10	6	119.3	.08067	1.130	3.109	4,906		8,275	.4066x10 ⁻²
12	7	117.0	.05817	1.076	3.393	4,844		8,246	.2994x10 ⁻²
14	8	115.6	.04249	1.026	3.662	4,806		8,228	.2220x10 ⁻²
16	9	114.6	.03121	.9801	3.906	4,782		8,215	.1649x10 ⁻²
18	10	113.9	.02296	.9389	4.137	4,765		8,210	.1223x10 ⁻²
20	11	113.4	.01692	.9028	4.353	4,753		8,202	.9064x10 ⁻³
22	12	112.9	.01244	.8700	4.546	4,743		8,197	.6694x10 ⁻³

Stage	10	12	14	16	18	20	22
1	.810	.810	.810	.810	.810	.810	.810
2	.839	.843	.844	.845	.845	.845	.845
3	.837	.850	.857	.860	.862	.862	.862
4	.805	.837	.853	.861	.865	.867	.868
5	.735	.802	.836	.853	.862	.866	.868
6	.436	.731	.800	.834	.852	.861	.865
7	.523	.431	.728	.798	.832	.850	.859
8	.600	.571	.428	.726	.796	.831	.848
9	.649	.584	.504	.425	.724	.794	.829
10	.664	.632	.573	.500	.424	.723	.793
11		.663	.618	.566	.496	.422	.721
12		.669	.650	.608	.561	.494	.421
13			.672	.638	.602	.558	.492
14			.672	.661	.629	.597	.556
15				.677	.650	.623	.594
16				.674	.668	.642	.619
17					.681	.658	.636
18					.675	.672	.650
19						.683	.662
20						.676	.657
21							.685
22							.676

L(d)	<u>Temperature Profiles (°F)</u>						
	<u>10</u>	<u>12</u>	<u>14</u>	<u>16</u>	<u>18</u>	<u>20</u>	<u>22</u>
<u>Stage</u>							
1	174.2	170.2	167.8	166.3	165.2	164.3	163.7
2	198.9	193.0	189.6	187.6	186.2	185.2	184.5
3	215.4	206.1	200.9	198.0	196.1	194.9	194.1
4	233.8	217.7	209.3	204.7	202.0	200.3	199.2
5	263.7	233.7	218.8	211.0	206.6	204.1	202.5
6	319.3	262.5	233.6	219.4	211.9	207.7	205.3
7	332.4	317.5	261.7	233.5	219.7	212.4	208.4
8	345.7	328.3	316.5	261.3	233.4	219.9	212.8
9	364.9	337.6	326.0	315.9	261.0	233.4	220.1
10	401.7	348.7	333.3	324.7	315.5	260.9	233.5
11		366.5	340.5	330.8	323.9	315.3	260.8
12		402.3	350.4	336.1	329.4	323.4	315.2
13			367.4	342.3	333.6	328.5	323.1
14			402.7	351.5	337.9	332.2	328.0
15				368.1	343.5	335.4	331.3
16				403.0	352.2	339.1	333.9
17					368.5	344.2	336.6
18					403.2	352.7	339.9
19						368.8	344.8
20						403.3	353.1
21							369.0
22							403.4

FIGURE I-1

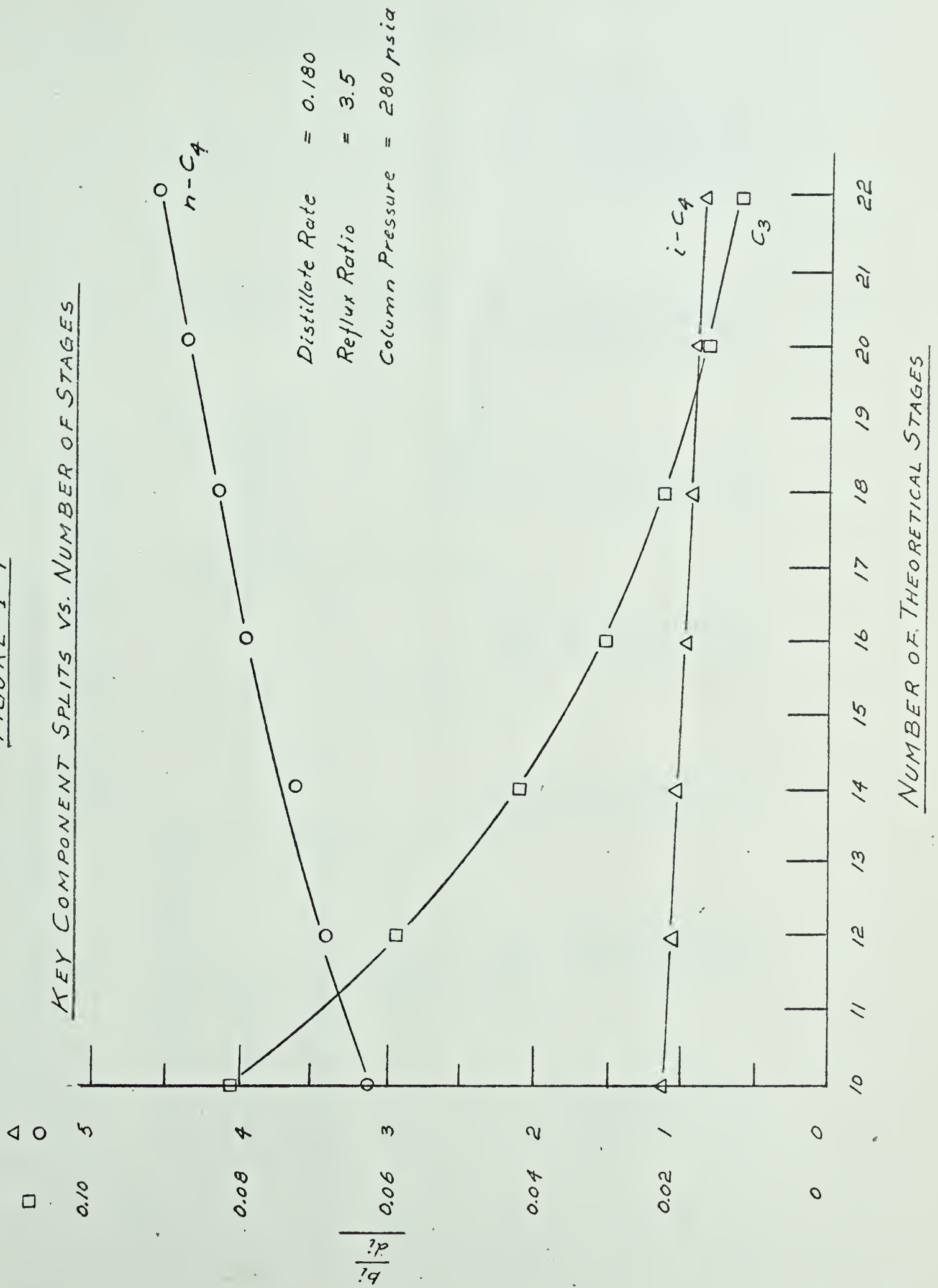


TABLE I-2

VARYING FEED STAGE LOCATION

2(a) Fixed Independent Variables

Column Pressure	=	280 psi
Distillate Rate	=	0.180 lb. moles lb. mole feed
Reflux Ratio	=	3.500
Number of Theoretical Stages	=	14

2(b) Column Dependent Variables

N_T	T_D	O_F	C_3 bi/di	$i-C_4$ bi/di	$n-C_4$ bi/di	$\frac{BTU}{lb. \text{ mole feed}}$ Q_C	Q_R	X_{B-C_3}
4	117.9		.01474	1.355	3.774	5,008	8,449	.7196x10 ⁻³
5	116.3		.01838	1.241	3.751	4,903	8,344	.9835x10 ⁻³
6	115.6		.02386	1.155	3.745	4,848	8,287	.1270x10 ⁻²
7	115.3		.03168	1.086	3.726	4,819	8,251	.1673x10 ⁻²
8	115.7		.04248	1.026	3.661	4,806	8,228	.2221x10 ⁻²
9	116.1		.05760	.9777	3.550	4,803	8,206	.2967x10 ⁻²
10	117.2		.07875	.9344	3.346	4,810	8,183	.3977x10 ⁻²
11	119.2		.1092	.8965	3.020	4,825	8,146	.5368x10 ⁻²

2(c) Vapour Profiles $\left(\frac{\text{lb. moles}}{\text{lb. mole feed}} \right)$

<u>N_F</u> (Feed Stage)	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
<u>Stage</u>								
1	.810	.810	.810	.810	.810	.810	.810	.810
2	.807	.827	.836	.841	.844	.847	.849	.852
3	.748	.807	.835	.849	.857	.862	.866	.870
4	.444	.740	.805	.837	.853	.862	.869	.875
5	.505	.436	.734	.802	.836	.854	.865	.872
6	.568	.503	.431	.730	.800	.834	.853	.865
7	.607	.566	.501	.429	.728	.797	.832	.851
8	.633	.605	.566	.502	.428	.725	.794	.828
9	.652	.632	.607	.568	.504	.427	.723	.789
10	.667	.651	.634	.610	.573	.508	.427	.719
11	.680	.668	.655	.640	.618	.581	.515	.427
12	.694	.683	.673	.663	.650	.629	.692	.525
13	.705	.694	.687	.680	.672	.661	.641	.606
14	.696	.686	.681	.676	.672	.666	.657	.641

2(d) Temperature Profiles °F

<u>N_F</u>	<u>(Feed Stage)</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
<u>Stage</u>									
1		177.9	172.5	169.6	168.2	167.8	168.0	168.9	170.7
2		213.0	200.6	194.4	191.2	189.6	189.1	189.4	190.5
3		250.9	223.4	210.6	204.2	200.9	199.3	198.9	199.4
4		310.9	255.7	228.4	215.7	209.3	206.0	204.6	204.4
5		318.9	313.0	258.4	231.4	218.8	212.5	209.4	208.3
6		324.0	321.1	314.3	260.1	233.6	221.2	215.2	212.5
7		327.5	326.3	322.7	315.4	261.7	235.7	223.7	218.3
8		330.4	330.0	328.2	324.2	316.5	263.5	238.3	227.2
9		333.3	333.4	332.5	330.2	326.0	318.0	266.1	242.4
10		336.9	337.3	336.9	335.6	333.3	328.8	320.4	270.3
11		342.2	342.6	342.5	341.9	340.5	338.0	333.4	324.5
12		351.0	351.5	351.5	351.1	350.4	349.0	346.5	341.8
13		367.6	367.9	368.0	367.8	367.4	366.7	365.4	363.
14		402.9	403.0	403.0	402.9	402.7	402.4	401.9	401.0

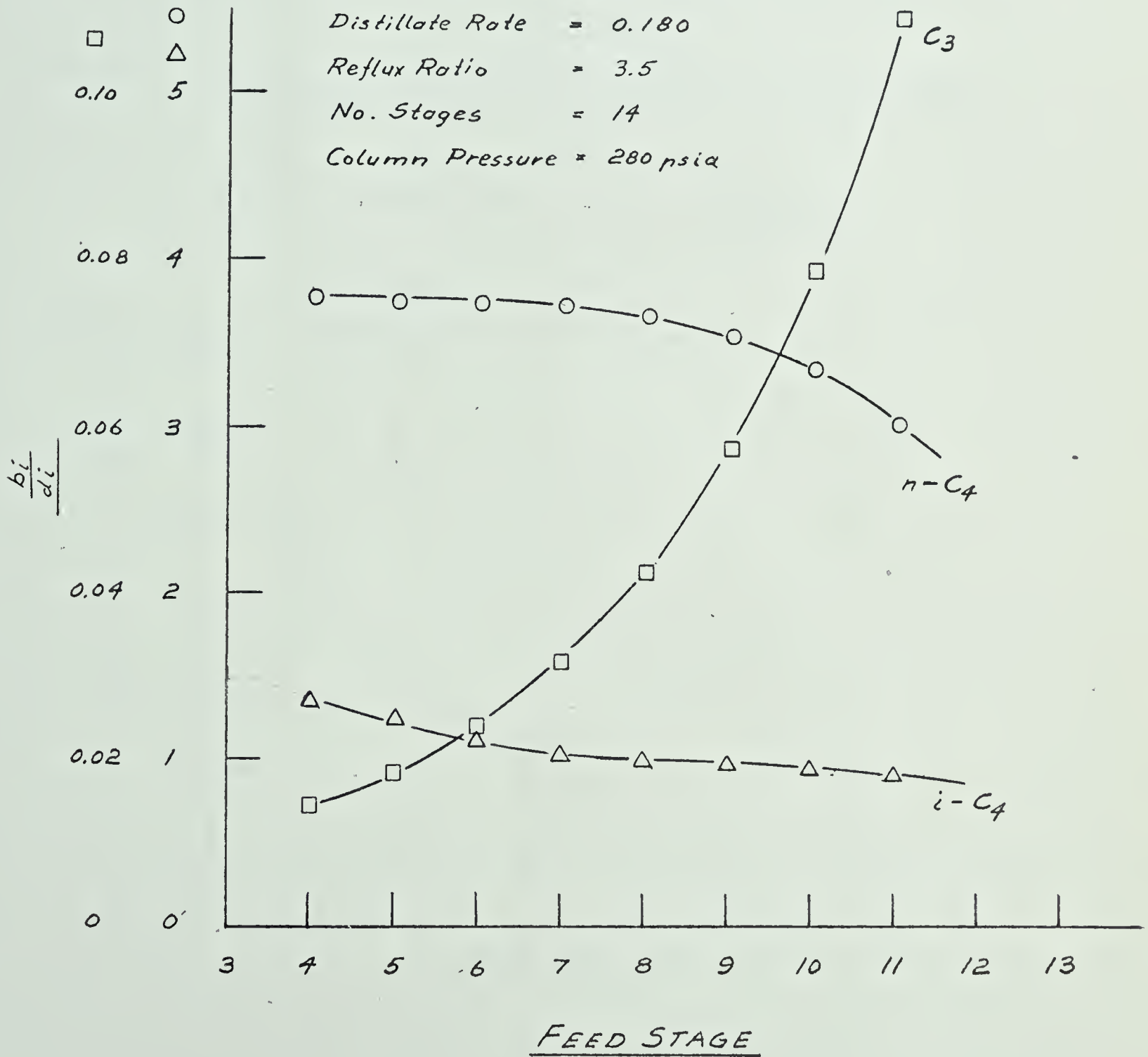
FIGURE I-2KEY COMPONENT SPLITS VS. FEED STAGE

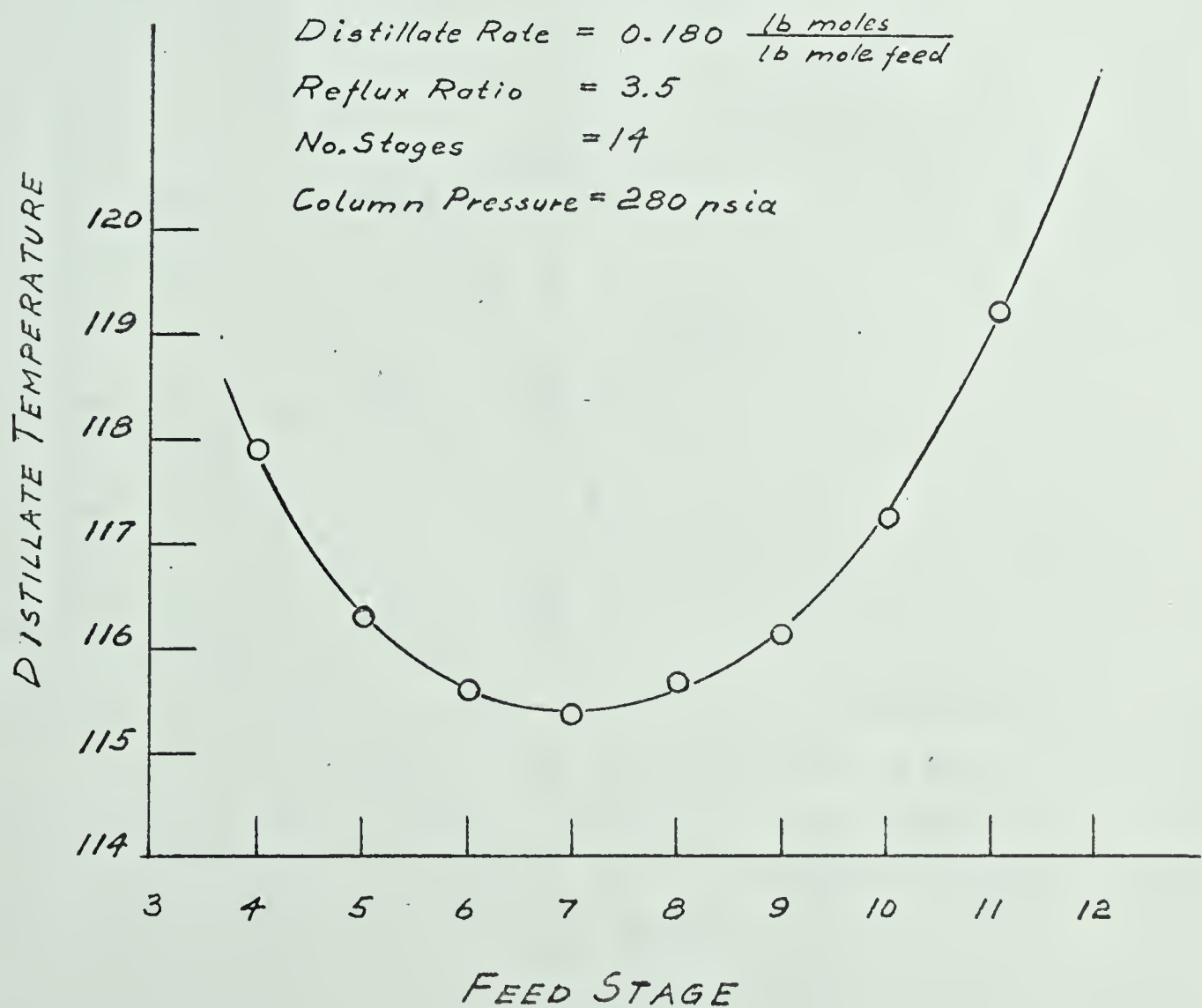
FIGURE I-3DISTILLATE TEMPERATURE vs. FEED STAGE

FIGURE I-4
VAPOUR PROFILES VS. FEED STAGE

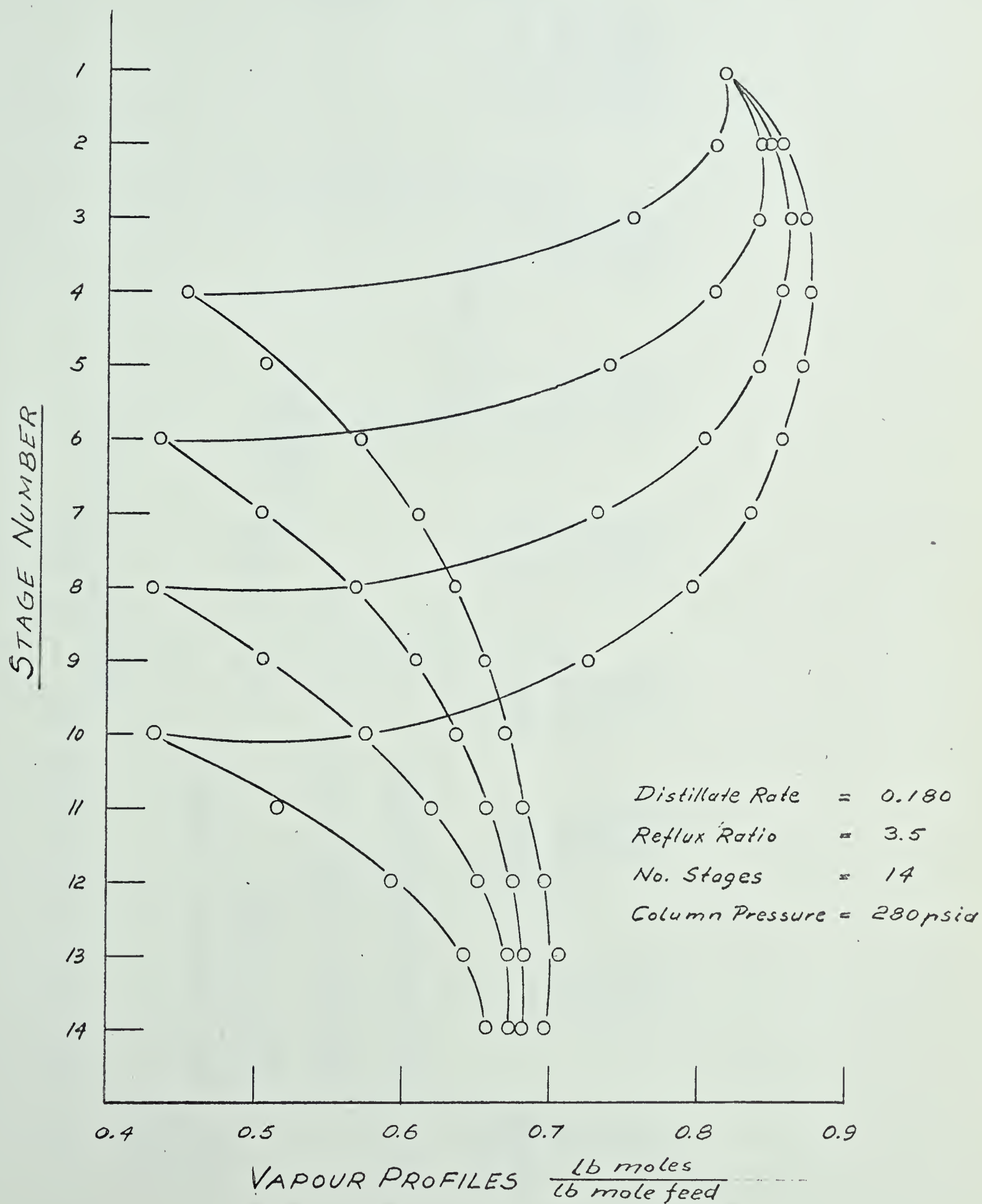


TABLE I-3

Varying The Reflux Ratio

3(a)		Fixed Independent variables	
Column Pressure	=	280 psia	
Distillate Rate	=	0.180 lb. moles lb. mole feed	
Number of Theoretical Stages	=	14	
Feed Stage	=	8	

3(b)		Column Dependent Variables	
Reflux Ratio	T_D	$\frac{C_3}{bi/di}$	$\frac{i-C_4}{bi/di}$
	O_F	$\frac{n-C_4}{bi/di}$	$\frac{BTU}{lb. mole feed}$
			$\frac{Q_C}{Q_R}$
			X_B-C_3

2.50	119.8	.1100	1.777	2.795	3,490	6,843	.5411x10 ⁻²
3.00	117.1	.06495	1.094	3.286	4,144	7,543	.3324x10 ⁻²
3.50	115.6	.04249	1.026	3.662	4,806	8,228	.2221x10 ⁻²
4.00	114.6	.02992	.9731	3.953	5,471	8,906	.1582x10 ⁻²
4.50	114.0	.02223	.9305	4.183	6,139	9,582	.1184x10 ⁻²

3(c) Vapour Profiles (lb. moles)
(lb. mole feed)

<u>Reflux Ratio</u>	<u>2.5</u>	<u>3.0</u>	<u>3.5</u>	<u>4.0</u>	<u>4.5</u>
<u>Stage</u>					
1	.630	.720	.810	.900	.990
2	.652	.748	.844	.940	1.037
3	.656	.757	.857	.957	1.057
4	.648	.751	.853	.955	1.058
5	.630	.733	.836	.939	1.042
6	.599	.699	.800	.901	1.002
7	.547	.636	.728	.821	.917
8	.289	.356	.428	.502	.578
9	.347	.427	.504	.581	.656
10	.406	.493	.573	.650	.725
11	.453	.540	.618	.693	.766
12	.493	.575	.650	.722	.792
13	.526	.602	.672	.740	.806
14	.542	.609	.672	.732	.792

3(d) Temperature Profiles (°F)

<u>Reflux Ratio</u>	<u>2.5</u>	<u>3.0</u>	<u>3.5</u>	<u>4.0</u>	<u>4.5</u>
<u>Stage</u>					
1	170.0	168.4	167.8	167.7	167.8
2	190.3	189.5	189.6	190.1	190.6
3	201.6	200.6	200.9	201.5	202.2
4	211.2	209.4	209.3	209.7	210.2
5	222.6	219.7	218.8	218.6	218.6
6	239.6	235.6	233.6	232.4	231.5
7	268.5	264.6	261.7	259.4	257.4
8	319.6	318.4	216.5	314.1	311.5
9	328.1	327.7	326.0	323.7	320.9
10	335.4	335.0	333.3	330.8	328.1
11	342.8	342.3	340.5	338.3	335.8
12	352.3	351.8	350.4	348.6	346.8
13	368.0	368.1	367.4	366.6	365.6
14	401.4	402.3	402.7	403.0	403.2

FIGURE I-5KEY COMPONENT SPLITS VS. REFLUX RATIO

Distillate Rate = 0.180

No. Stages = 14

Feed Stage = 8

Column Pressure = 280 psia

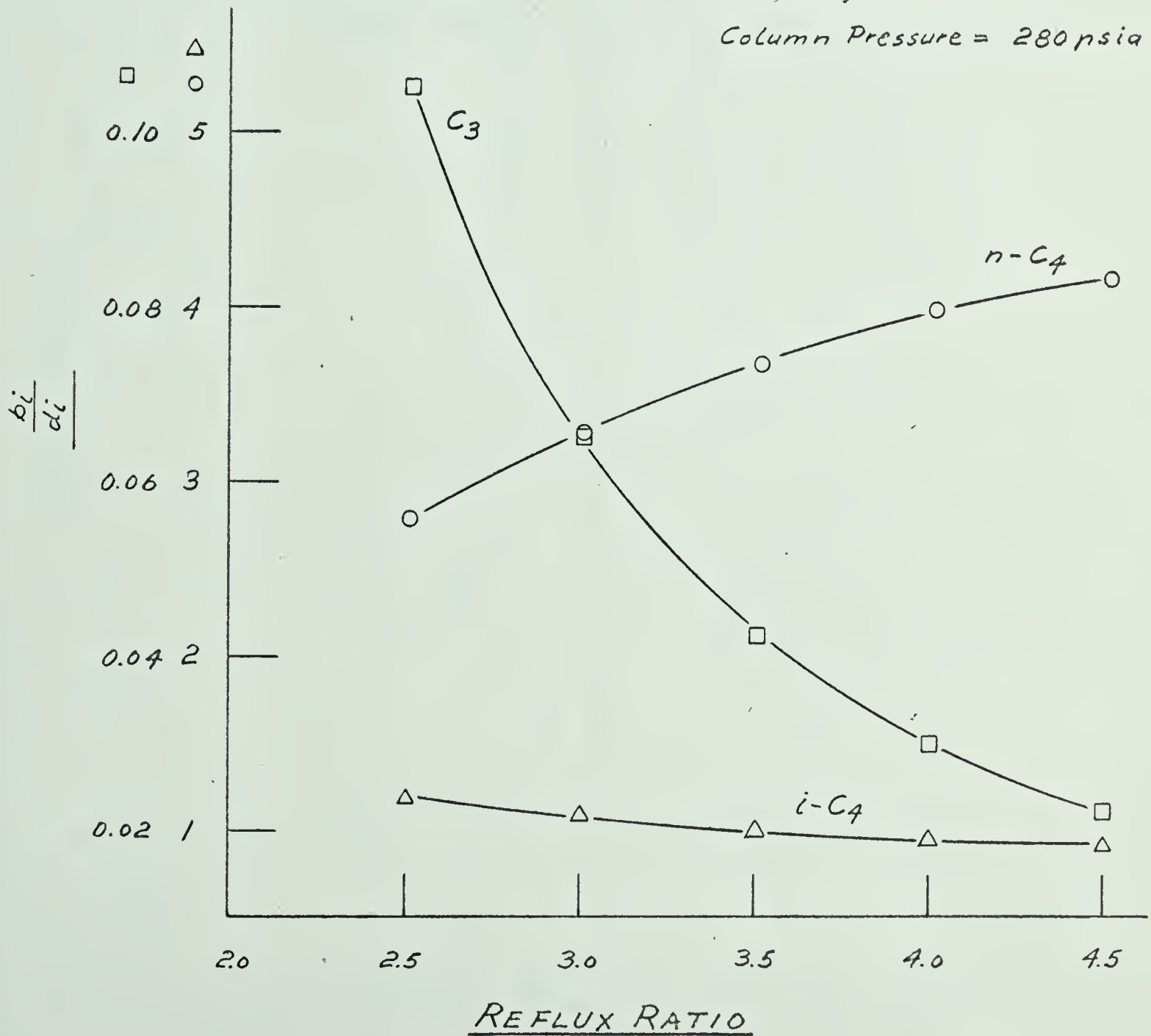


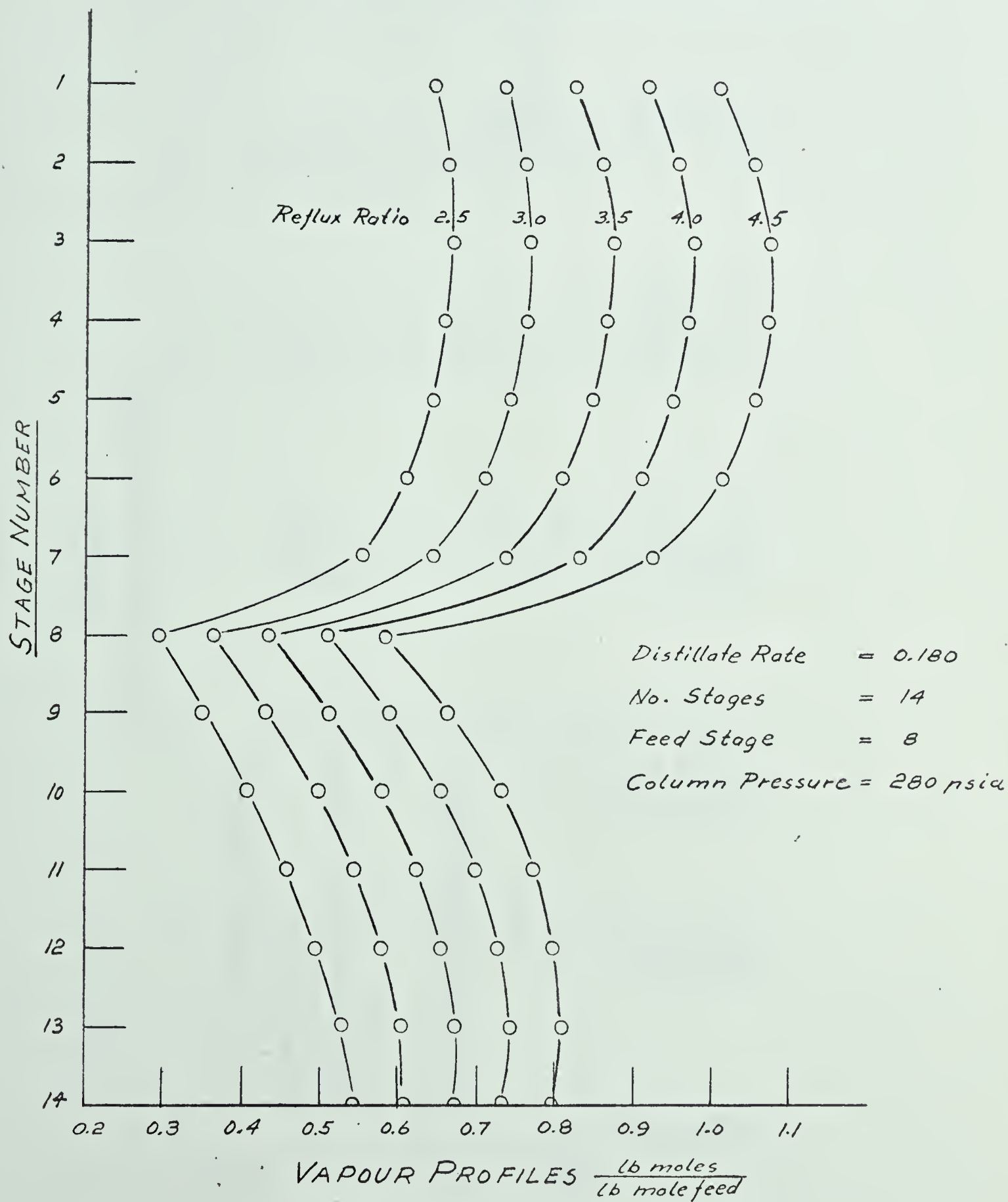
FIGURE I-6VAPOUR PROFILES VS. REFLUX RATIO

TABLE I-4
VARYING THE DISTILLATE RATE

(a) Fixed Independent Variables			
Column Pressure	=	280 psia	
Reflux Ratio	=	3.500	
Number of Theoretical Stages	=	14	
Feed Stage	=	8	
(b) Column Dependent Variables			
Distillate Rate	OF TD	X_{B-C_3}	X_{B-C_4}
.150	80.4	$.8383 \times 10^{-2}$	$.8799 \times 10^{-1}$
.200	132.4	$.1116 \times 10^{-2}$	$.6045 \times 10^{-1}$
.250	162.8	$.2134 \times 10^{-3}$	$.1755 \times 10^{-1}$
.300	197.5	$.6322 \times 10^{-4}$	$.4851 \times 10^{-2}$
.350	221.0	$.2864 \times 10^{-4}$	$.2102 \times 10^{-2}$
.400	238.0	$.1334 \times 10^{-4}$	$.8554 \times 10^{-3}$
		$X_{B_n-C_4}$	BTU lb. mole feed
			Q_C
			Q_R
			3,733
			5,402
			6,897
			8,948
			10,593
			12,189
			6,478
			9,231
			11,737
			14,562
			16,938
			19,314

4(c) Vapour Profiles $\left(\frac{\text{lb. moles}}{\text{lb. mole feed}} \right)$

Distillate Rate	<u>.150</u>	<u>.200</u>	<u>.250</u>	<u>.300</u>	<u>.350</u>	<u>.400</u>
Stage						
1	.675	.900	1.125	1.350	1.575	1.800
2	.671	.949	1.175	1.430	1.684	1.919
3	.671	.962	1.173	1.467	1.709	1.932
4	.666	.955	1.154	1.443	1.703	1.909
5	.654	.933	1.126	1.426	1.679	1.867
6	.625	.893	1.088	1.391	1.633	1.810
7	.565	.816	1.021	1.318	1.551	1.727
8	.288	.508	.714	.994	1.216	1.408
9	.325	.606	.887	1.231	1.486	1.728
10	.375	.681	.985	1.333	1.588	1.849
11	.416	.726	1.038	1.377	1.628	1.903
12	.453	.757	1.068	1.391	1.637	1.920
13	.485	.776	1.074	1.375	1.616	1.898
14	.503	.768	1.036	1.312	1.546	1.821

4(d) Temperature Profiles (°F)

<u>Distillate Rate</u>	<u>.150</u>	<u>.200</u>	<u>.250</u>	<u>.300</u>	<u>.350</u>	<u>.400</u>
<u>Stage</u>						
1	132.1	180.9	206.0	243.9	263.3	277.0
2	161.5	199.3	223.5	262.5	278.8	291.7
3	179.5	208.9	235.2	273.2	287.2	300.8
4	192.2	216.7	246.1	280.9	293.5	308.8
5	204.4	226.1	257.7	288.1	300.1	317.5
6	221.4	240.7	271.6	297.1	308.8	328.1
7	253.4	267.4	292.4	312.0	323.0	342.4
8	312.5	319.2	334.3	345.9	353.9	370.5
9	319.5	329.7	347.7	359.5	368.7	387.8
10	325.8	337.5	357.4	369.2	379.8	400.6
11	332.3	345.6	366.8	379.0	391.4	412.8
12	341.0	356.6	378.5	391.6	405.7	436.8
13	356.2	374.7	396.5	410.7	425.8	445.5
14	390.5	410.2	429.2	443.3	457.3	473.4

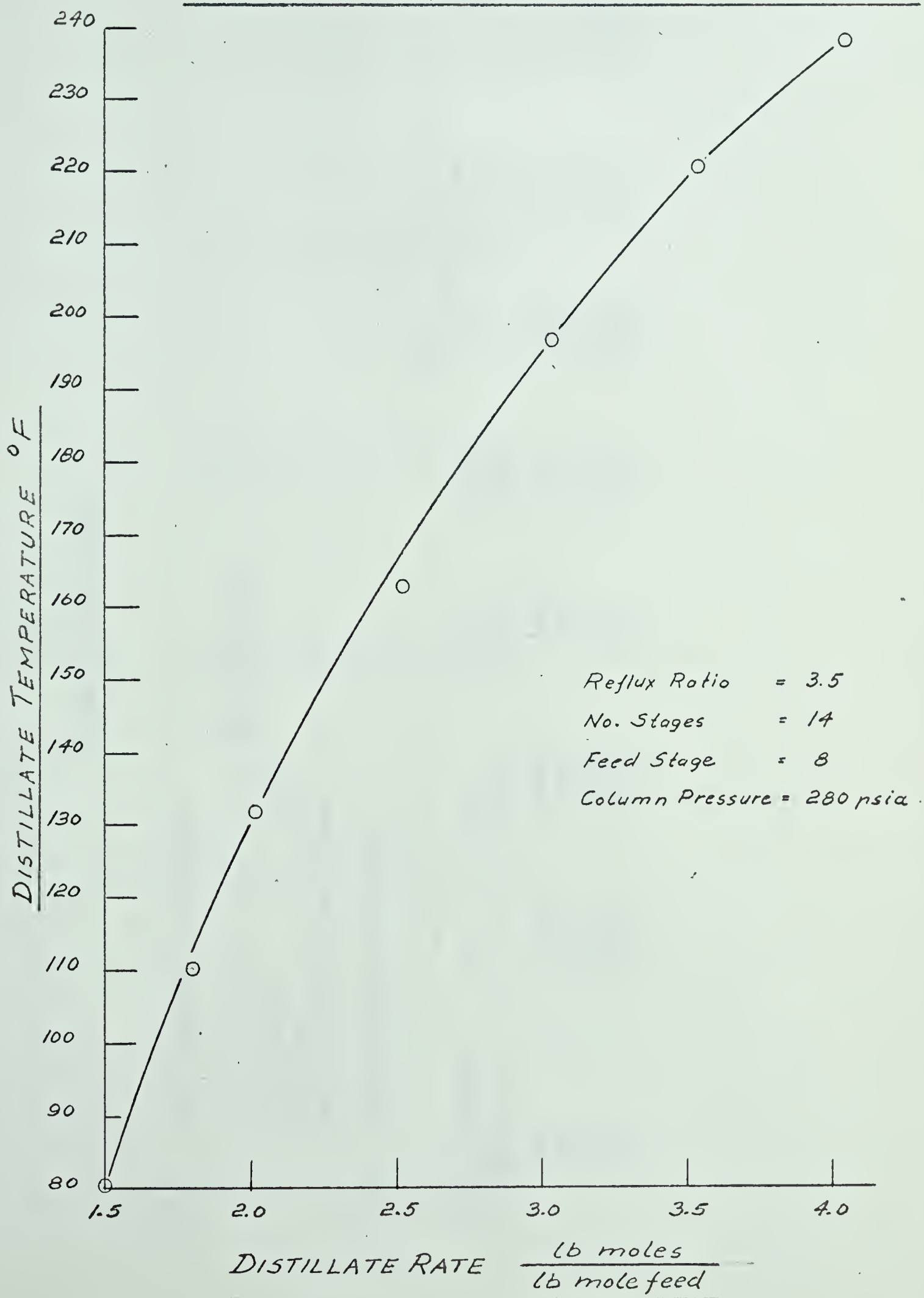
FIGURE I-7DISTILLATE TEMPERATURE VS. DISTILLATE RATE

TABLE I-5
VARYING COLUMN PRESSURE

5(a) Fixed Independent Variables

Distillate Rate	=	0.180	(lb. moles lb. mole feed)
Reflux Ratio	=	3.500	
Feed Stage	=	8	
Number of Theoretical Stages	=	14	

5(b) Column Dependent Variables

Column Pressure Psia	T_D °F	C_3 bi/di	$i-C_4$ bi/di	$n-C_4$ bi/di	BTU lb. mole feed	X_{B-C_3}
200	91.6	.01529	.8441	4.601	5,080	.8212x10 ⁻³
250	107.2	.02946	.9608	3.989	4,906	.1559x10 ⁻²
300	120.8	.05275	1.067	3.459	4,739	.2731x10 ⁻²
350	133.5	.08829	1.153	3.004	4,586	.4420x10 ⁻²
400	145.0	.1322	1.211	2.642	4,418	.2239x10 ⁻¹

5(c) Vapour Profiles $\left(\frac{\text{lb. moles}}{\text{lb. mole feed}} \right)$

Column Pressure Psig	200	250	300	350	400
Stage					
1	.810	.810	.810	.810	.810
2	.838	.840	.842	.845	.844
3	.848	.852	.855	.859	.858
4	.847	.849	.851	.852	.852
5	.836	.834	.832	.829	.829
6	.811	.803	.794	.784	.785
7	.753	.736	.721	.707	.713
8	.452	.440	.430	.426	.420
9	.520	.513	.502	.498	.493
10	.576	.573	.573	.576	.603
11	.605	.612	.620	.636	.679
12	.624	.638	.659	.683	.743
13	.633	.652	.682	.719	.789
14	.622	.652	.688	.738	.827

5(d) Temperature Profiles (°F)

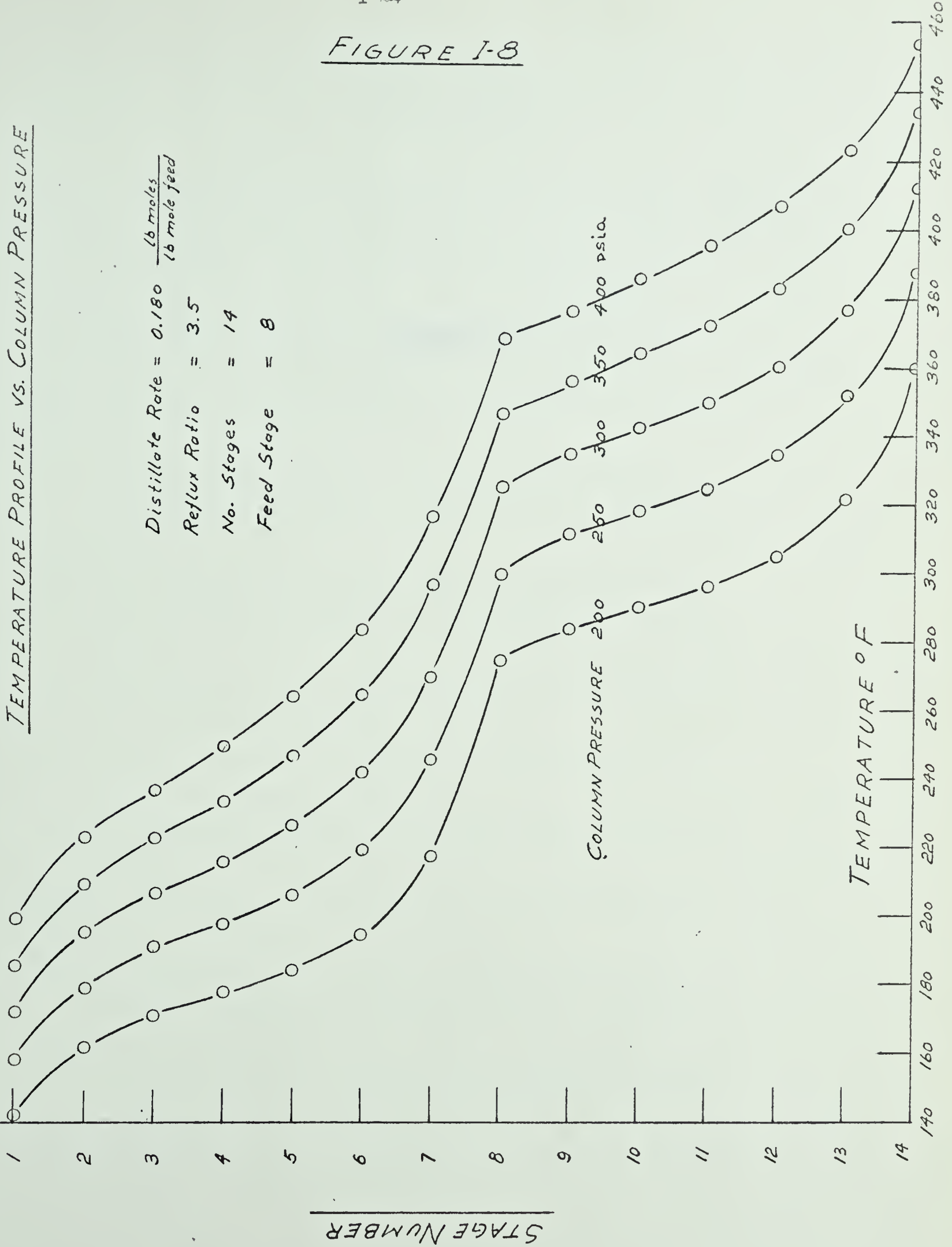
Stage	Column Pressure Psig				
	<u>200</u>	<u>250</u>	<u>300</u>	<u>350</u>	<u>400</u>
1	143.0	159.1	173.2	186.5	198.1
2	162.6	180.1	195.5	210.2	222.9
3	171.7	190.5	207.4	223.7	237.7
4	177.8	197.9	216.4	234.6	250.1
5	184.2	206.2	226.7	247.1	264.3
6	194.8	219.3	242.4	265.3	284.3
7	218.1	245.8	271.4	295.8	316.3
8	275.3	302.2	325.9	347.3	368.3
9	284.4	311.8	335.4	356.6	376.9
10	290.4	318.5	342.8	364.5	386.2
11	296.6	353.3	350.2	372.7	395.8
12	305.5	334.9	360.3	383.4	407.1
13	322.1	351.7	377.4	401.0	423.6
14	359.1	387.5	412.3	434.9	456.4

FIGURE I-8TEMPERATURE PROFILE VS. COLUMN PRESSUREDistillate Rate = $0.180 \frac{\text{lb moles}}{\text{lb mole feed}}$

Reflux Ratio = 3.5

No. Stages = 14

Feed Stage = 8



APPENDIX II

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL DEW POINT CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	100.00	100.00	0.1000	H2S	0.0960	0.0960	0.960	1.039	0.0960	102.81
400.0	100.00	100.00	0.1200	METHANE	0.7370	0.7370	6.142	6.305	0.7370	102.81
400.0	100.00	100.00	0.7800	N-BUTANE	0.1670	0.1670	0.214	0.211	0.1670	102.81
400.0	100.00	100.00	0.2000	H2S	0.1710	0.1710	0.855	1.050	0.1710	104.30
400.0	100.00	100.00	0.1120	METHANE	0.6700	0.6700	5.982	6.276	0.6700	104.30
400.0	100.00	100.00	0.6880	N-BUTANE	0.1590	0.1590	0.231	0.218	0.1590	104.30
400.0	100.00	100.00	0.3000	H2S	0.2800	0.2800	0.933	1.059	0.2800	105.74
400.0	100.00	100.00	0.1050	METHANE	0.5750	0.5750	5.476	6.218	0.5750	105.74
400.0	100.00	100.00	0.5950	N-BUTANE	0.1450	0.1450	0.244	0.226	0.1450	105.74
400.0	100.00	100.00	0.4000	H2S	0.3700	0.3700	0.925	1.053	0.3700	105.79
400.0	100.00	100.00	0.0950	METHANE	0.5000	0.5000	5.263	6.149	0.5000	105.79
400.0	100.00	100.00	0.5050	N-BUTANE	0.1300	0.1300	0.257	0.229	0.1300	105.79
400.0	100.00	100.00	0.5000	H2S	0.4730	0.4730	0.946	1.046	0.4730	105.79
400.0	100.00	100.00	0.0860	METHANE	0.4150	0.4150	4.826	6.064	0.4150	105.79
400.0	100.00	100.00	0.4140	N-BUTANE	0.1120	0.1120	0.271	0.234	0.1120	105.79
400.0	100.00	100.00	0.6000	H2S	0.5710	0.5710	0.952	1.038	0.5710	105.74
400.0	100.00	100.00	0.0730	METHANE	0.3350	0.3350	4.589	5.980	0.3350	105.74
400.0	100.00	100.00	0.3270	N-BUTANE	0.0940	0.0940	0.287	0.239	0.0940	105.74
400.0	100.00	100.00	0.7000	H2S	0.6600	0.6600	0.943	1.022	0.6600	104.94
400.0	100.00	100.00	0.0580	METHANE	0.2650	0.2650	4.569	5.889	0.2650	104.94
400.0	100.00	100.00	0.2420	N-BUTANE	0.0750	0.0750	0.310	0.242	0.0750	104.94
400.0	100.00	100.00	0.8000	H2S	0.7440	0.7440	0.930	1.006	0.7440	104.07
400.0	100.00	100.00	0.0430	METHANE	0.2000	0.2000	4.651	5.802	0.2000	104.07
400.0	100.00	100.00	0.1570	N-BUTANE	0.0560	0.0560	0.357	0.247	0.0560	104.07
400.0	100.00	100.00	0.9000	H2S	0.8480	0.8480	0.942	0.996	0.8480	103.73
400.0	100.00	100.00	0.0230	METHANE	0.1190	0.1190	5.174	5.719	0.1190	103.73
400.0	100.00	100.00	0.0770	N-BUTANE	0.0330	0.0330	0.429	0.259	0.0330	103.73
400.0	100.00	100.00	0.0000	H2S	-0.0000	-0.0000	-0.000	1.022	-0.0000	100.60
400.0	100.00	100.00	0.1220	METHANE	0.8240	0.8240	6.754	6.334	0.8240	100.60
400.0	100.00	100.00	0.8780	N-BUTANE	0.1760	0.1760	0.200	0.202	0.1760	100.60

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL							DEW POINT			CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)		
400.0		100.00		H2S	0.9990	0.9880	0.989	0.990	0.9880	103.70		
400.0		100.00		METHANE	0.0010	0.0120	12.000	5.658	0.0120	103.70		
400.0		100.00		N-BUTANE	0.0000	0.0000	0.000	0.286	0.0000	103.70		
800.0		100.00		H2S	0.1000	0.0770	0.770	0.671	0.0770	106.47		
800.0		100.00		METHANE	0.2430	0.8000	3.292	3.452	0.8000	106.47		
800.0		100.00		N-BUTANE	0.6570	0.1230	0.187	0.188	0.1230	106.47		
800.0		100.00		H2S	0.2000	0.1450	0.725	0.705	0.1450	112.79		
800.0		100.00		METHANE	0.2250	0.7350	3.267	3.455	0.7350	112.79		
800.0		100.00		N-BUTANE	0.5750	0.1200	0.209	0.206	0.1200	112.79		
800.0		100.00		H2S	0.3000	0.2300	0.767	0.724	0.2300	116.45		
800.0		100.00		METHANE	0.2060	0.6620	3.214	3.428	0.6620	116.45		
800.0		100.00		N-BUTANE	0.4940	0.1080	0.219	0.221	0.1080	116.45	H _i	
800.0		100.00		H2S	0.4000	0.2970	0.742	0.729	0.2970	117.86	N	
800.0		100.00		METHANE	0.1870	0.6080	3.251	3.396	0.6080	117.86		
800.0		100.00		N-BUTANE	0.4130	0.0950	0.230	0.230	0.0950	117.86		
800.0		100.00		H2S	0.5000	0.3550	0.710	0.730	0.3550	118.54		
800.0		100.00		METHANE	0.1650	0.5630	3.412	3.364	0.5630	118.54		
800.0		100.00		N-BUTANE	0.3350	0.0820	0.245	0.237	0.0820	118.54		
800.0		100.00		H2S	0.6000	0.4280	0.713	0.717	0.4280	117.01		
800.0		100.00		METHANE	0.1420	0.5120	3.606	3.309	0.5120	117.01		
800.0		100.00		N-BUTANE	0.2580	0.0600	0.233	0.242	0.0600	117.01		
800.0		100.00		H2S	0.7000	0.4880	0.697	0.710	0.4880	116.30		
800.0		100.00		METHANE	0.1170	0.4700	4.017	3.271	0.4700	116.30		
800.0		100.00		N-BUTANE	0.1830	0.0420	0.230	0.249	0.0420	116.30		
800.0		100.00		H2S	0.8000	0.5390	0.674	0.696	0.5390	114.34		
800.0		100.00		METHANE	0.0900	0.4380	4.867	3.236	0.4380	114.34		
800.0		100.00		N-BUTANE	0.1100	0.0230	0.209	0.255	0.0230	114.34		
800.0		100.00		H2S	0.9000	0.5680	0.631	0.684	0.5680	112.42		
800.0		100.00		METHANE	0.0640	0.4220	6.594	3.216	0.4220	112.42		
800.0		100.00		N-BUTANE	0.0360	0.0100	0.278	0.259	0.0100	112.42		

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL							BUB POINT			CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)		
400.0		100.00		H2S	0.1000	0.0960	0.960	0.991	0.0991	97.86		
400.0		100.00		METHANE	0.1200	0.7370	6.142	6.221	0.7466	97.86		
400.0		100.00		N-BUTANE	0.7800	0.1670	0.214	0.198	0.1544	97.86		
400.0		100.00		H2S	0.2000	0.1710	0.855	0.944	0.1889	93.46		
400.0		100.00		METHANE	0.1120	0.6700	5.982	6.079	0.6808	93.46		
400.0		100.00		N-BUTANE	0.6880	0.1590	0.231	0.189	0.1303	93.46		
400.0		100.00		H2S	0.3000	0.2800	0.933	0.898	0.2694	88.98		
400.0		100.00		METHANE	0.1050	0.5750	5.476	5.932	0.6229	88.98		
400.0		100.00		N-BUTANE	0.5950	0.1450	0.244	0.181	0.1078	88.98		
400.0		100.00		H2S	0.4000	0.3700	0.925	0.883	0.3532	87.98		
400.0		100.00		METHANE	0.0950	0.5000	5.263	5.840	0.5548	87.98		
400.0		100.00		N-BUTANE	0.5050	0.1300	0.257	0.182	0.0920	87.98		
400.0		100.00		H2S	0.5000	0.4730	0.946	0.862	0.4312	86.36		
400.0		100.00		METHANE	0.0860	0.4150	4.826	5.738	0.4934	86.36		
400.0		100.00		N-BUTANE	0.4140	0.1120	0.271	0.182	0.0754	86.36		
400.0		100.00		H2S	0.6000	0.5710	0.952	0.871	0.5223	88.03		
400.0		100.00		METHANE	0.0730	0.3350	4.589	5.687	0.4151	88.03		
400.0		100.00		N-BUTANE	0.3270	0.0940	0.287	0.191	0.0626	88.03		
400.0		100.00		H2S	0.7000	0.6600	0.943	0.889	0.6223	90.88		
400.0		100.00		METHANE	0.0580	0.2650	4.569	5.655	0.3280	90.88		
400.0		100.00		N-BUTANE	0.2420	0.0750	0.310	0.205	0.0497	90.88		
400.0		100.00		H2S	0.8000	0.7440	0.930	0.905	0.7236	93.34		
400.0		100.00		METHANE	0.0430	0.2000	4.651	5.620	0.2417	93.34		
400.0		100.00		N-BUTANE	0.1570	0.0560	0.357	0.221	0.0348	93.34		
400.0		100.00		H2S	0.9000	0.8480	0.942	0.946	0.8513	98.54		
400.0		100.00		METHANE	0.0230	0.1190	5.174	5.632	0.1295	98.54		
400.0		100.00		N-BUTANE	0.0770	0.0330	0.429	0.250	0.0192	98.54		
400.0		100.00		H2S	0.0000	-0.0000	-0.000	1.136	0.0000	111.95		
400.0		100.00		METHANE	0.1220	0.8240	6.754	6.509	0.7941	111.95		
400.0		100.00		N-BUTANE	0.8780	0.1760	0.200	0.235	0.2059	111.95		

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL							BUB POINT			CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)		
400.0		100.00		H2S	0.9990	0.9880	0.989	0.995	0.9943	104.28		
400.0		100.00		METHANE	0.0010	0.0120	12.000	5.664	0.0057	104.28		
400.0		100.00		N-BUTANE	0.0000	0.0000	0.000	0.288	0.0000	104.28		
800.0		100.00		H2S	0.1000	0.0770	0.770	0.625	0.0625	98.15		
800.0		100.00		METHANE	0.2430	0.8000	3.292	3.398	0.8257	98.15		
800.0		100.00		N-BUTANE	0.6570	0.1230	0.187	0.170	0.1120	98.15		
800.0		100.00		H2S	0.2000	0.1450	0.725	0.651	0.1301	103.22		
800.0		100.00		METHANE	0.2250	0.7350	3.267	3.394	0.7637	103.22		
800.0		100.00		N-BUTANE	0.5750	0.1200	0.209	0.185	0.1063	103.22		
800.0		100.00		H2S	0.3000	0.2300	0.767	0.677	0.2032	108.39		
800.0		100.00		METHANE	0.2060	0.6620	3.214	3.387	0.6976	108.39		
800.0		100.00		N-BUTANE	0.4940	0.1080	0.219	0.201	0.0993	108.39		H ₁
800.0		100.00		H2S	0.4000	0.2970	0.742	0.700	0.2801	112.92		
800.0		100.00		METHANE	0.1870	0.6080	3.251	3.371	0.6304	112.92		
800.0		100.00		N-BUTANE	0.4130	0.0950	0.230	0.217	0.0896	112.92		
800.0		100.00		H2S	0.5000	0.3550	0.710	0.731	0.3657	118.87		
800.0		100.00		METHANE	0.1650	0.5630	3.412	3.360	0.5544	118.87		
800.0		100.00		N-BUTANE	0.3350	0.0820	0.245	0.239	0.0799	118.87		
800.0		100.00		H2S	0.6000	0.4280	0.713	0.762	0.4573	124.68		
800.0		100.00		METHANE	0.1420	0.5120	3.606	3.345	0.4750	124.68		
800.0		100.00		N-BUTANE	0.2580	0.0600	0.233	0.263	0.0678	124.68		
800.0		100.00		H2S	0.7000	0.4880	0.697	0.796	0.5573	130.96		
800.0		100.00		METHANE	0.1170	0.4700	4.017	3.329	0.3895	130.96		
800.0		100.00		N-BUTANE	0.1830	0.0420	0.230	0.291	0.0533	130.96		
800.0		100.00		H2S	0.8000	0.5390	0.674	0.832	0.6659	137.51		
800.0		100.00		METHANE	0.0900	0.4380	4.867	3.314	0.2983	137.51		
800.0		100.00		N-BUTANE	0.1100	0.0230	0.209	0.326	0.0358	137.51		
800.0		100.00		H2S	0.9000	0.5680	0.631	0.862	0.7758	142.75		
800.0		100.00		METHANE	0.0640	0.4220	6.594	3.301	0.2112	142.75		
800.0		100.00		N-BUTANE	0.0360	0.0100	0.278	0.363	0.0131	142.75		

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

DEW POINT NEW CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	400.0	100.00	100.00	H2S	0.1000	0.0960	0.960	1.362	0.0960	100.48
400.0	400.0	100.00	100.00	METHANE	0.1200	0.7370	6.142	6.389	0.7370	100.48
400.0	400.0	100.00	100.00	N-BUTANE	0.7800	0.1670	0.214	0.205	0.1670	100.48
400.0	400.0	100.00	100.00	H2S	0.2000	0.1710	0.855	1.337	0.1710	100.18
400.0	400.0	100.00	100.00	METHANE	0.1120	0.6700	5.982	6.439	0.6700	100.18
400.0	400.0	100.00	100.00	N-BUTANE	0.6880	0.1590	0.231	0.207	0.1590	100.18
400.0	400.0	100.00	100.00	H2S	0.3000	0.2800	0.933	1.290	0.2800	99.13
400.0	400.0	100.00	100.00	METHANE	0.1050	0.5750	5.476	6.526	0.5750	99.13
400.0	400.0	100.00	100.00	N-BUTANE	0.5950	0.1450	0.244	0.209	0.1450	99.13
400.0	400.0	100.00	100.00	H2S	0.4000	0.3700	0.925	1.235	0.3700	97.14
400.0	400.0	100.00	100.00	METHANE	0.0950	0.5000	5.263	6.619	0.5000	97.14
400.0	400.0	100.00	100.00	N-BUTANE	0.5050	0.1300	0.257	0.208	0.1300	97.14
400.0	400.0	100.00	100.00	H2S	0.5000	0.4730	0.946	1.170	0.4730	95.01
400.0	400.0	100.00	100.00	METHANE	0.0860	0.4150	4.826	6.796	0.4150	95.01
400.0	400.0	100.00	100.00	N-BUTANE	0.4140	0.1120	0.271	0.210	0.1120	95.01
400.0	400.0	100.00	100.00	H2S	0.6000	0.5710	0.952	1.107	0.5710	93.30
400.0	400.0	100.00	100.00	METHANE	0.0730	0.3350	4.589	7.088	0.3350	93.30
400.0	400.0	100.00	100.00	N-BUTANE	0.3270	0.0940	0.287	0.215	0.0940	93.30
400.0	400.0	100.00	100.00	H2S	0.7000	0.6600	0.943	1.042	0.6600	91.52
400.0	400.0	100.00	100.00	METHANE	0.0580	0.2650	4.569	7.560	0.2650	91.52
400.0	400.0	100.00	100.00	N-BUTANE	0.2420	0.0750	0.310	0.226	0.0750	91.52
400.0	400.0	100.00	100.00	H2S	0.8000	0.7440	0.930	0.990	0.7440	90.63
400.0	400.0	100.00	100.00	METHANE	0.0430	0.2000	4.651	8.343	0.2000	90.63
400.0	400.0	100.00	100.00	N-BUTANE	0.1570	0.0560	0.357	0.250	0.0560	90.63
400.0	400.0	100.00	100.00	H2S	0.9000	0.8480	0.942	0.962	0.8480	91.97
400.0	400.0	100.00	100.00	METHANE	0.0230	0.1190	5.174	9.870	0.1190	91.97
400.0	400.0	100.00	100.00	N-BUTANE	0.0770	0.0330	0.429	0.309	0.0330	91.97
400.0	400.0	100.00	100.00	H2S	0.0000	-0.0000	-0.000	1.389	-0.0000	100.60
400.0	400.0	100.00	100.00	METHANE	0.1220	0.8240	6.754	6.334	0.8240	100.60
400.0	400.0	100.00	100.00	N-BUTANE	0.8780	0.1760	0.200	0.202	0.1760	100.60

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						DEW POINT		NEW CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0		100.00		H2S	0.9990	0.9880	0.989	0.989	0.9880	96.88
400.0		100.00		METHANE	0.0010	0.0120	12.000	12.582	0.0120	96.88
400.0		100.00		N-BUTANE	0.0000	0.0000	0.000	0.442	0.0000	96.88
800.0		100.00		H2S	0.1000	0.0770	0.770	0.837	0.0770	102.69
800.0		100.00		METHANE	0.2430	0.8000	3.292	3.509	0.8000	102.69
800.0		100.00		N-BUTANE	0.6570	0.1230	0.187	0.181	0.1230	102.69
800.0		100.00		H2S	0.2000	0.1450	0.725	0.841	0.1450	105.98
800.0		100.00		METHANE	0.2250	0.7350	3.267	3.575	0.7350	105.98
800.0		100.00		N-BUTANE	0.5750	0.1200	0.209	0.193	0.1200	105.98
800.0		100.00		H2S	0.3000	0.2300	0.767	0.815	0.2300	106.20
800.0		100.00		METHANE	0.2060	0.6620	3.214	3.655	0.6620	106.20
800.0		100.00		N-BUTANE	0.4940	0.1080	0.219	0.201	0.1080	106.20
800.0		100.00		H2S	0.4000	0.2970	0.742	0.784	0.2970	105.25
800.0		100.00		METHANE	0.1870	0.6080	3.251	3.747	0.6080	105.25
800.0		100.00		N-BUTANE	0.4130	0.0950	0.230	0.207	0.0950	105.25
800.0		100.00		H2S	0.5000	0.3550	0.710	0.754	0.3550	104.29
800.0		100.00		METHANE	0.1650	0.5630	3.412	3.872	0.5630	104.29
800.0		100.00		N-BUTANE	0.3350	0.0820	0.245	0.214	0.0820	104.29
800.0		100.00		H2S	0.6000	0.4280	0.713	0.700	0.4280	101.66
800.0		100.00		METHANE	0.1420	0.5120	3.606	4.167	0.5120	101.66
800.0		100.00		N-BUTANE	0.2580	0.0600	0.233	0.226	0.0600	101.66
800.0		100.00		H2S	0.7000	0.4880	0.697	0.668	0.4880	101.48
800.0		100.00		METHANE	0.1170	0.4700	4.017	4.604	0.4700	101.48
800.0		100.00		N-BUTANE	0.1830	0.0420	0.230	0.251	0.0420	101.48
800.0		100.00		H2S	0.8000	0.5390	0.674	0.644	0.5390	101.51
800.0		100.00		METHANE	0.0900	0.4380	4.867	5.254	0.4380	101.51
800.0		100.00		N-BUTANE	0.1100	0.0230	0.209	0.289	0.0230	101.51
800.0		100.00		H2S	0.9000	0.5680	0.631	0.634	0.5680	101.61
800.0		100.00		METHANE	0.0640	0.4220	6.594	5.796	0.4220	101.61
800.0		100.00		N-BUTANE	0.0360	0.0100	0.278	0.323	0.0100	101.61

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

BUB POINT NEW CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	100.00	100.00	100.00	H2S	0.1000	0.0960	0.960	1.205	0.1205	87.53
400.0	100.00	100.00	100.00	METHANE	0.1200	0.7370	6.142	6.205	0.7445	87.53
400.0	100.00	100.00	100.00	N-BUTANE	0.7800	0.1670	0.214	0.173	0.1350	87.53
400.0	100.00	100.00	100.00	H2S	0.2000	0.1710	0.855	1.052	0.2105	76.25
400.0	100.00	100.00	100.00	METHANE	0.1120	0.6700	5.982	6.124	0.6859	76.25
400.0	100.00	100.00	100.00	N-BUTANE	0.6880	0.1590	0.231	0.151	0.1037	76.25
400.0	100.00	100.00	100.00	H2S	0.3000	0.2800	0.933	0.928	0.2784	66.93
400.0	100.00	100.00	100.00	METHANE	0.1050	0.5750	5.476	6.109	0.6415	66.93
400.0	100.00	100.00	100.00	N-BUTANE	0.5950	0.1450	0.244	0.135	0.0802	66.93
400.0	100.00	100.00	100.00	H2S	0.4000	0.3700	0.925	0.855	0.3419	62.46
400.0	100.00	100.00	100.00	METHANE	0.0950	0.5000	5.263	6.236	0.5924	62.46
400.0	100.00	100.00	100.00	N-BUTANE	0.5050	0.1300	0.257	0.130	0.0657	62.46
400.0	100.00	100.00	100.00	H2S	0.5000	0.4730	0.946	0.786	0.3932	58.25
400.0	100.00	100.00	100.00	METHANE	0.0860	0.4150	4.826	6.443	0.5541	58.25
400.0	100.00	100.00	100.00	N-BUTANE	0.4140	0.1120	0.271	0.127	0.0527	58.25
400.0	100.00	100.00	100.00	H2S	0.6000	0.5710	0.952	0.759	0.4551	58.60
400.0	100.00	100.00	100.00	METHANE	0.0730	0.3350	4.589	6.855	0.5004	58.60
400.0	100.00	100.00	100.00	N-BUTANE	0.3270	0.0940	0.287	0.136	0.0445	58.60
400.0	100.00	100.00	100.00	H2S	0.7000	0.6600	0.943	0.754	0.5275	61.63
400.0	100.00	100.00	100.00	METHANE	0.0580	0.2650	4.569	7.498	0.4349	61.63
400.0	100.00	100.00	100.00	N-BUTANE	0.2420	0.0750	0.310	0.155	0.0376	61.63
400.0	100.00	100.00	100.00	H2S	0.8000	0.7440	0.930	0.759	0.6070	65.69
400.0	100.00	100.00	100.00	METHANE	0.0430	0.2000	4.651	8.457	0.3636	65.69
400.0	100.00	100.00	100.00	N-BUTANE	0.1570	0.0560	0.357	0.187	0.0294	65.69
400.0	100.00	100.00	100.00	H2S	0.9000	0.8480	0.942	0.832	0.7486	77.32
400.0	100.00	100.00	100.00	METHANE	0.0230	0.1190	5.174	10.043	0.2310	77.32
400.0	100.00	100.00	100.00	N-BUTANE	0.0770	0.0330	0.429	0.265	0.0204	77.32
400.0	100.00	100.00	100.00	H2S	0.0000	-0.0000	-0.000	1.525	0.0000	111.95
400.0	100.00	100.00	100.00	METHANE	0.1220	0.8240	6.754	6.509	0.7941	111.95
400.0	100.00	100.00	100.00	N-BUTANE	0.8780	0.1760	0.200	0.235	0.2059	111.95

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

BUB POINT

NEW CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	100.00			H2S	0.9990	0.9880	0.989	0.988	0.9874	96.82
400.0	100.00			METHANE	0.0010	0.0120	12.000	12.580	0.0126	96.82
400.0	100.00			N-BUTANE	0.0000	0.0000	0.000	0.442	0.0000	96.82
800.0	100.00			H2S	0.1000	0.0770	0.770	0.739	0.0739	87.76
800.0	100.00			METHANE	0.2430	0.8000	3.292	3.401	0.8264	87.76
800.0	100.00			N-BUTANE	0.6570	0.1230	0.187	0.152	0.0998	87.76

BUBPT MORE THAN THIRTY TRIALS ARE REQ.

800.0	100.00			H2S	0.2000	0.1450	0.725	0.699	0.1398	84.66
800.0	100.00			METHANE	0.2250	0.7350	3.267	3.438	0.7735	84.66
800.0	100.00			N-BUTANE	0.5750	0.1200	0.209	0.151	0.0867	84.66
800.0	100.00			H2S	0.3000	0.2300	0.767	1.050	0.3151	118.91
800.0	100.00			METHANE	0.2060	0.6620	3.214	1.505	0.3101	118.91
800.0	100.00			N-BUTANE	0.4940	0.1080	0.219	0.759	0.3749	118.91
800.0	100.00			H2S	0.4000	0.2970	0.742	1.016	0.4064	109.13
800.0	100.00			METHANE	0.1870	0.6080	3.251	1.407	0.2630	109.13
800.0	100.00			N-BUTANE	0.4130	0.0950	0.230	0.800	0.3305	109.13

800.0	100.00			H2S	0.5000	0.3550	0.710	0.984	0.4922	104.19
800.0	100.00			METHANE	0.1650	0.5630	3.412	1.375	0.2269	104.19
800.0	100.00			N-BUTANE	0.3350	0.0820	0.245	0.838	0.2809	104.19
800.0	100.00			H2S	0.6000	0.4280	0.713	0.957	0.5744	102.31
800.0	100.00			METHANE	0.1420	0.5120	3.606	1.381	0.1961	102.31
800.0	100.00			N-BUTANE	0.2580	0.0600	0.233	0.890	0.2295	102.31
800.0	100.00			H2S	0.7000	0.4880	0.697	0.935	0.6544	107.45
800.0	100.00			METHANE	0.1170	0.4700	4.017	1.445	0.1691	107.45
800.0	100.00			N-BUTANE	0.1830	0.0420	0.230	0.964	0.1765	107.45

BUBPT MORE THAN THIRTY TRIALS ARE REQ.

800.0	100.00			H2S	0.8000	0.5390	0.674	0.921	0.7361	120.48
800.0	100.00			METHANE	0.0900	0.4380	4.867	1.606	0.1444	120.48
800.0	100.00			N-BUTANE	0.1100	0.0230	0.209	1.086	0.1194	120.48
800.0	100.00			H2S	0.9000	0.5680	0.631	0.682	0.6134	110.42
800.0	100.00			METHANE	0.0640	0.4220	6.594	5.841	0.3738	110.42
800.0	100.00			N-BUTANE	0.0360	0.0100	0.278	0.357	0.0129	110.42

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

DEW POINT

GRAYSON STREED CONSTANTS

P PSIA	T DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	100.00	H2S	0.1000	0.0960	0.960	1.095	0.0960	105.95
400.0	100.00	METHANE	0.1200	0.7370	6.142	5.798	0.7370	105.95
400.0	100.00	N-BUTANE	0.7800	0.1670	0.214	0.213	0.1670	105.95
400.0	100.00	H2S	0.2000	0.1710	0.855	1.102	0.1710	106.98
400.0	100.00	METHANE	0.1120	0.6700	5.982	5.771	0.6700	106.98
400.0	100.00	N-BUTANE	0.6880	0.1590	0.231	0.218	0.1590	106.98
400.0	100.00	H2S	0.3000	0.2800	0.933	1.106	0.2800	107.80
400.0	100.00	METHANE	0.1050	0.5750	5.476	5.715	0.5750	107.80
400.0	100.00	N-BUTANE	0.5950	0.1450	0.244	0.224	0.1450	107.80
400.0	100.00	H2S	0.4000	0.3700	0.925	1.095	0.3700	107.37
400.0	100.00	METHANE	0.0950	0.5000	5.263	5.643	0.5000	107.37
400.0	100.00	N-BUTANE	0.5050	0.1300	0.257	0.227	0.1300	107.37
400.0	100.00	H2S	0.5000	0.4730	0.946	1.082	0.4730	106.78
400.0	100.00	METHANE	0.0860	0.4150	4.826	5.556	0.4150	106.78
400.0	100.00	N-BUTANE	0.4140	0.1120	0.271	0.229	0.1120	106.78
400.0	100.00	H2S	0.6000	0.5710	0.952	1.068	0.5710	106.14
400.0	100.00	METHANE	0.0730	0.3350	4.589	5.468	0.3350	106.14
400.0	100.00	N-BUTANE	0.3270	0.0940	0.287	0.233	0.0940	106.14
400.0	100.00	H2S	0.7000	0.6600	0.943	1.046	0.6600	104.78
400.0	100.00	METHANE	0.0580	0.2650	4.569	5.371	0.2650	104.78
400.0	100.00	N-BUTANE	0.2420	0.0750	0.310	0.234	0.0750	104.78
400.0	100.00	H2S	0.8000	0.7440	0.930	1.024	0.7440	103.35
400.0	100.00	METHANE	0.0430	0.2000	4.651	5.276	0.2000	103.35
400.0	100.00	N-BUTANE	0.1570	0.0560	0.357	0.238	0.0560	103.35
400.0	100.00	H2S	0.9000	0.8480	0.942	1.006	0.8480	102.29
400.0	100.00	METHANE	0.0230	0.1190	5.174	5.182	0.1190	102.29
400.0	100.00	N-BUTANE	0.0770	0.0330	0.429	0.247	0.0330	102.29
400.0	100.00	H2S	0.0000	-0.0000	-0.000	1.081	-0.0000	104.28
400.0	100.00	METHANE	0.1220	0.8240	6.754	5.824	0.8240	104.28
400.0	100.00	N-BUTANE	0.8780	0.1760	0.200	0.205	0.1760	104.28

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						DEW POINT		GRAYSON STREED CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0		100.00		H2S	0.9990	0.9880	0.989	0.990	0.9880	101.26
400.0		100.00		METHANE	0.0010	0.0120	12.000	5.103	0.0120	101.26
400.0		100.00		N-BUTANE	0.0000	0.0000	0.000	0.270	0.0000	101.26
800.0		100.00		H2S	0.1000	0.0770	0.770	0.724	0.0770	113.47
800.0		100.00		METHANE	0.2430	0.8000	3.292	3.304	0.8000	113.47
800.0		100.00		N-BUTANE	0.6570	0.1230	0.187	0.189	0.1230	113.47
800.0		100.00		H2S	0.2000	0.1450	0.725	0.755	0.1450	118.36
800.0		100.00		METHANE	0.2250	0.7350	3.267	3.312	0.7350	118.36
800.0		100.00		N-BUTANE	0.5750	0.1200	0.209	0.205	0.1200	118.36
800.0		100.00		H2S	0.3000	0.2300	0.767	0.767	0.2300	120.59
800.0		100.00		METHANE	0.2060	0.6620	3.214	3.284	0.6620	120.59
800.0		100.00		N-BUTANE	0.4940	0.1080	0.219	0.217	0.1080	120.59
800.0		100.00		H2S	0.4000	0.2970	0.742	0.767	0.2970	120.94
800.0		100.00		METHANE	0.1870	0.6080	3.251	3.247	0.6080	120.94
800.0		100.00		N-BUTANE	0.4130	0.0950	0.230	0.223	0.0950	120.94
800.0		100.00		H2S	0.5000	0.3550	0.710	0.763	0.3550	120.68
800.0		100.00		METHANE	0.1650	0.5630	3.412	3.209	0.5630	120.68
800.0		100.00		N-BUTANE	0.3350	0.0820	0.245	0.228	0.0820	120.68
800.0		100.00		H2S	0.6000	0.4280	0.713	0.742	0.4280	118.05
800.0		100.00		METHANE	0.1420	0.5120	3.606	3.141	0.5120	118.05
800.0		100.00		N-BUTANE	0.2580	0.0600	0.233	0.230	0.0600	118.05
800.0		100.00		H2S	0.7000	0.4880	0.697	0.729	0.4880	116.39
800.0		100.00		METHANE	0.1170	0.4700	4.017	3.092	0.4700	116.39
800.0		100.00		N-BUTANE	0.1830	0.0420	0.230	0.235	0.0420	116.39
800.0		100.00		H2S	0.8000	0.5390	0.674	0.709	0.5390	113.58
800.0		100.00		METHANE	0.0900	0.4380	4.867	3.043	0.4380	113.58
800.0		100.00		N-BUTANE	0.1100	0.0230	0.209	0.239	0.0230	113.58
800.0		100.00		H2S	0.9000	0.5680	0.631	0.694	0.5680	111.18
800.0		100.00		METHANE	0.0640	0.4220	6.594	3.014	0.4220	111.18
800.0		100.00		N-BUTANE	0.0360	0.0100	0.278	0.242	0.0100	111.18

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						BUB POINT		GRAYSON STREED CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0		100.00		H2S	0.1000	0.0960	0.960	1.151	0.1151	111.26
400.0		100.00		METHANE	0.1200	0.7370	6.142	5.885	0.7062	111.26
400.0		100.00		N-BUTANE	0.7800	0.1670	0.214	0.229	0.1787	111.26
400.0		100.00		H2S	0.2000	0.1710	0.855	1.076	0.2152	104.70
400.0		100.00		METHANE	0.1120	0.6700	5.982	5.699	0.6383	104.70
400.0		100.00		N-BUTANE	0.6880	0.1590	0.231	0.213	0.1466	104.70
400.0		100.00		H2S	0.3000	0.2800	0.933	1.007	0.3020	98.55
400.0		100.00		METHANE	0.1050	0.5750	5.476	5.519	0.5795	98.55
400.0		100.00		N-BUTANE	0.5950	0.1450	0.244	0.199	0.1185	98.55
400.0		100.00		H2S	0.4000	0.3700	0.925	0.972	0.3888	95.68
400.0		100.00		METHANE	0.0950	0.5000	5.263	5.397	0.5127	95.68
400.0		100.00		N-BUTANE	0.5050	0.1300	0.257	0.195	0.0986	95.68
400.0		100.00		H2S	0.5000	0.4730	0.946	0.935	0.4676	92.59
400.0		100.00		METHANE	0.0860	0.4150	4.826	5.270	0.4533	92.59
400.0		100.00		N-BUTANE	0.4140	0.1120	0.271	0.191	0.0792	92.59
400.0		100.00		H2S	0.6000	0.5710	0.952	0.927	0.5565	92.49
400.0		100.00		METHANE	0.0730	0.3350	4.589	5.197	0.3793	92.49
400.0		100.00		N-BUTANE	0.3270	0.0940	0.287	0.196	0.0642	92.49
400.0		100.00		H2S	0.7000	0.6600	0.943	0.931	0.6518	93.58
400.0		100.00		METHANE	0.0580	0.2650	4.569	5.144	0.2984	93.58
400.0		100.00		N-BUTANE	0.2420	0.0750	0.310	0.206	0.0498	93.58
400.0		100.00		H2S	0.8000	0.7440	0.930	0.934	0.7468	94.50
400.0		100.00		METHANE	0.0430	0.2000	4.651	5.094	0.2190	94.50
400.0		100.00		N-BUTANE	0.1570	0.0560	0.357	0.218	0.0342	94.50
400.0		100.00		H2S	0.9000	0.8480	0.942	0.960	0.8644	97.88
400.0		100.00		METHANE	0.0230	0.1190	5.174	5.090	0.1171	97.88
400.0		100.00		N-BUTANE	0.0770	0.0330	0.429	0.241	0.0185	97.88
400.0		100.00		H2S	0.0000	-0.0000	-0.000	1.327	0.0000	126.35
400.0		100.00		METHANE	0.1220	0.8240	6.754	6.220	0.7588	126.35
400.0		100.00		N-BUTANE	0.8780	0.1760	0.200	0.275	0.2412	126.35

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

BUB POINT

GRAYSON STREED CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0	400.0	100.00	100.00	H2S	0.9990	0.9880	0.989	0.996	0.9949	101.84
400.0	400.0	100.00	100.00	METHANE	0.0010	0.0120	12.000	5.110	0.0051	101.84
400.0	400.0	100.00	100.00	N-BUTANE	0.0000	0.0000	0.000	0.272	0.0000	101.84
800.0	800.0	100.00	100.00	H2S	0.1000	0.0770	0.770	0.725	0.0725	113.52
800.0	800.0	100.00	100.00	METHANE	0.2430	0.8000	3.292	3.307	0.8037	113.52
800.0	800.0	100.00	100.00	N-BUTANE	0.6570	0.1230	0.187	0.189	0.1239	113.52
800.0	800.0	100.00	100.00	H2S	0.2000	0.1450	0.725	0.736	0.1472	115.49
800.0	800.0	100.00	100.00	METHANE	0.2250	0.7350	3.267	3.284	0.7389	115.49
800.0	800.0	100.00	100.00	N-BUTANE	0.5750	0.1200	0.209	0.198	0.1139	115.49
800.0	800.0	100.00	100.00	H2S	0.3000	0.2300	0.767	0.749	0.2247	117.85
800.0	800.0	100.00	100.00	METHANE	0.2060	0.6620	3.214	3.261	0.6718	117.85
800.0	800.0	100.00	100.00	N-BUTANE	0.4940	0.1080	0.219	0.210	0.1035	117.85
800.0	800.0	100.00	100.00	H2S	0.4000	0.2970	0.742	0.760	0.3040	119.93
800.0	800.0	100.00	100.00	METHANE	0.1870	0.6080	3.251	3.233	0.6046	119.93
800.0	800.0	100.00	100.00	N-BUTANE	0.4130	0.0950	0.230	0.221	0.0915	119.93
800.0	800.0	100.00	100.00	H2S	0.5000	0.3550	0.710	0.780	0.3899	123.40
800.0	800.0	100.00	100.00	METHANE	0.1650	0.5630	3.412	3.213	0.5302	123.40
800.0	800.0	100.00	100.00	N-BUTANE	0.3350	0.0820	0.245	0.239	0.0799	123.40
800.0	800.0	100.00	100.00	H2S	0.6000	0.4280	0.713	0.800	0.4801	126.97
800.0	800.0	100.00	100.00	METHANE	0.1420	0.5120	3.606	3.192	0.4533	126.97
800.0	800.0	100.00	100.00	N-BUTANE	0.2580	0.0600	0.233	0.258	0.0666	126.97
800.0	800.0	100.00	100.00	H2S	0.7000	0.4880	0.697	0.824	0.5770	131.11
800.0	800.0	100.00	100.00	METHANE	0.1170	0.4700	4.017	3.173	0.3713	131.11
800.0	800.0	100.00	100.00	N-BUTANE	0.1830	0.0420	0.230	0.283	0.0518	131.11
800.0	800.0	100.00	100.00	H2S	0.8000	0.5390	0.674	0.852	0.6815	135.71
800.0	800.0	100.00	100.00	METHANE	0.0900	0.4380	4.867	3.157	0.2841	135.71
800.0	800.0	100.00	100.00	N-BUTANE	0.1100	0.0230	0.209	0.314	0.0345	135.71
800.0	800.0	100.00	100.00	H2S	0.9000	0.5680	0.631	0.874	0.7865	139.33
800.0	800.0	100.00	100.00	METHANE	0.0640	0.4220	6.594	3.141	0.2010	139.33
800.0	800.0	100.00	100.00	N-BUTANE	0.0360	0.0100	0.278	0.347	0.0125	139.33

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

DEW POINT

CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)
400.0	100.00	100.00	100.00	CO2	0.0500	0.1280	2.560	2.245	0.0570	102.73
400.0	100.00	100.00	100.00	METHANE	0.1020	0.6960	6.824	6.331	0.1099	102.73
400.0	100.00	100.00	100.00	N-BUTANE	0.8480	0.1760	0.208	0.211	0.8331	102.73
400.0	100.00	100.00	100.00	CO2	0.1000	0.2600	2.600	2.296	0.1132	106.13
400.0	100.00	100.00	100.00	METHANE	0.0820	0.5610	6.841	6.341	0.0885	106.13
400.0	100.00	100.00	100.00	N-BUTANE	0.8180	0.1790	0.219	0.224	0.7983	106.13
400.0	100.00	100.00	100.00	CO2	0.1500	0.4000	2.667	2.336	0.1712	108.93
400.0	100.00	100.00	100.00	METHANE	0.0620	0.4200	6.774	6.334	0.0663	108.93
400.0	100.00	100.00	100.00	N-BUTANE	0.7880	0.1800	0.228	0.236	0.7624	108.93
400.0	100.00	100.00	100.00	CO2	0.2000	0.5380	2.690	2.368	0.2272	111.36
400.0	100.00	100.00	100.00	METHANE	0.0410	0.2820	6.878	6.315	0.0447	111.36
400.0	100.00	100.00	100.00	N-BUTANE	0.7590	0.1800	0.237	0.247	0.7281	111.36
400.0	100.00	100.00	100.00	CO2	0.2500	0.6700	2.680	2.397	0.2795	113.74
400.0	100.00	100.00	100.00	METHANE	0.0200	0.1500	7.500	6.291	0.0238	113.74
400.0	100.00	100.00	100.00	N-BUTANE	0.7300	0.1800	0.247	0.258	0.6967	113.74
400.0	100.00	100.00	100.00	CO2	0.0000	-0.0000	-0.000	2.212	-0.0000	100.60
400.0	100.00	100.00	100.00	METHANE	0.1220	0.8240	6.754	6.334	0.1301	100.60
400.0	100.00	100.00	100.00	N-BUTANE	0.8780	0.1760	0.200	0.202	0.8699	100.60
400.0	100.00	100.00	100.00	CO2	0.3000	0.8200	2.733	2.430	0.3375	116.52
400.0	100.00	100.00	100.00	METHANE	0.0000	0.0000	0.000	6.257	0.0000	116.52
400.0	100.00	100.00	100.00	N-BUTANE	0.7000	0.1800	0.257	0.272	0.6625	116.52
800.0	100.00	100.00	100.00	CO2	0.1000	0.1740	1.740	1.311	0.1327	104.81
800.0	100.00	100.00	100.00	METHANE	0.2230	0.7000	3.139	3.434	0.2038	104.81
800.0	100.00	100.00	100.00	N-BUTANE	0.6770	0.1260	0.186	0.190	0.6635	104.81
800.0	100.00	100.00	100.00	CO2	0.2000	0.3100	1.550	1.351	0.2295	109.92
800.0	100.00	100.00	100.00	METHANE	0.1930	0.5630	2.917	3.422	0.1645	109.92
800.0	100.00	100.00	100.00	N-BUTANE	0.6070	0.1270	0.209	0.210	0.6060	109.92
800.0	100.00	100.00	100.00	CO2	0.3000	0.4380	1.460	1.371	0.3196	112.67
800.0	100.00	100.00	100.00	METHANE	0.1600	0.4380	2.737	3.388	0.1293	112.67
800.0	100.00	100.00	100.00	N-BUTANE	0.5400	0.1240	0.230	0.225	0.5512	112.67

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

CHAO-SEADER CONSTANTS

DEW POINT

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)
800.0	800.0	100.00	100.00	CO2	0.4000	0.5350	1.337	1.378	0.3882	114.01
800.0	800.0	100.00	100.00	METHANE	0.1260	0.3450	2.738	3.352	0.1029	114.01
800.0	800.0	100.00	100.00	N-BUTANE	0.4740	0.1200	0.253	0.236	0.5090	114.01
800.0	800.0	100.00	100.00	CO2	0.5000	0.6410	1.282	1.376	0.4657	114.32
800.0	800.0	100.00	100.00	METHANE	0.0930	0.2460	2.645	3.300	0.0746	114.32
800.0	800.0	100.00	100.00	N-BUTANE	0.4070	0.1130	0.278	0.246	0.4598	114.32
800.0	800.0	100.00	100.00	CO2	0.6000	0.7380	1.230	1.365	0.5406	113.46
800.0	800.0	100.00	100.00	METHANE	0.0550	0.1580	2.873	3.238	0.0488	113.46
800.0	800.0	100.00	100.00	N-BUTANE	0.3450	0.1040	0.301	0.253	0.4107	113.46
800.0	800.0	100.00	100.00	CO2	0.7000	0.8700	1.243	1.329	0.6544	109.70
800.0	800.0	100.00	100.00	METHANE	0.0140	0.0440	3.143	3.128	0.0141	109.70
800.0	800.0	100.00	100.00	N-BUTANE	0.2860	0.0860	0.301	0.259	0.3316	109.70
800.0	800.0	100.00	100.00	CO2	-0.0000	0.0000	0.000	1.249	0.0000	97.32
800.0	800.0	100.00	100.00	METHANE	0.2540	0.8770	3.453	3.430	0.2557	97.32
800.0	800.0	100.00	100.00	N-BUTANE	0.7460	0.1230	0.165	0.165	0.7443	97.32
800.0	800.0	100.00	100.00	CO2	0.7350	0.9200	1.252	1.320	0.6971	108.91
800.0	800.0	100.00	100.00	METHANE	0.0000	0.0000	0.000	3.085	0.0000	108.91
800.0	800.0	100.00	100.00	N-BUTANE	0.2650	0.0800	0.302	0.264	0.3030	108.91
1200.0	1200.0	100.00	100.00	CO2	0.1000	0.1100	1.100	0.976	0.1127	96.16
1200.0	1200.0	100.00	100.00	METHANE	0.3430	0.7730	2.254	2.436	0.3174	96.16
1200.0	1200.0	100.00	100.00	N-BUTANE	0.5570	0.1170	0.210	0.205	0.5700	96.16
1200.0	1200.0	100.00	100.00	CO2	0.2000	0.2200	1.100	0.994	0.2214	98.65
1200.0	1200.0	100.00	100.00	METHANE	0.3030	0.6670	2.201	2.402	0.2777	98.65
1200.0	1200.0	100.00	100.00	N-BUTANE	0.4970	0.1130	0.227	0.226	0.5010	98.65
1200.0	1200.0	100.00	100.00	CO2	0.3000	0.3470	1.157	1.019	0.3404	102.99
1200.0	1200.0	100.00	100.00	METHANE	0.2640	0.5430	2.057	2.358	0.2303	102.99
1200.0	1200.0	100.00	100.00	N-BUTANE	0.4360	0.1100	0.252	0.256	0.4293	102.99
1200.0	1200.0	100.00	100.00	CO2	0.4000	0.4400	1.100	1.043	0.4219	107.58
1200.0	1200.0	100.00	100.00	METHANE	0.2260	0.4500	1.991	2.318	0.1941	107.58
1200.0	1200.0	100.00	100.00	N-BUTANE	0.3740	0.1100	0.294	0.286	0.3841	107.58

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						BUB POINT			CHAO-SEADER CONSTANTS		
P PSIA	T DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)			
400.0	100.00	CO2	0.0500	0.1280	2.560	2.457	0.1228	115.75			
400.0	100.00	METHANE	0.1020	0.6960	6.824	6.527	0.6657	115.75			
400.0	100.00	N-BUTANE	0.8480	0.1760	0.208	0.249	0.2114	115.75			
400.0	100.00	CO2	0.1000	0.2600	2.600	2.502	0.2502	118.79			
400.0	100.00	METHANE	0.0820	0.5610	6.841	6.527	0.5352	118.79			
400.0	100.00	N-BUTANE	0.8180	0.1790	0.219	0.262	0.2146	118.79			
400.0	100.00	CO2	0.1500	0.4000	2.667	2.535	0.3803	121.26			
400.0	100.00	METHANE	0.0620	0.4200	6.774	6.511	0.4037	121.26			
400.0	100.00	N-BUTANE	0.7880	0.1800	0.228	0.274	0.2160	121.26			
400.0	100.00	CO2	0.2000	0.5380	2.690	2.575	0.5151	124.26			
400.0	100.00	METHANE	0.0410	0.2820	6.878	6.495	0.2663	124.26			
400.0	100.00	N-BUTANE	0.7590	0.1800	0.237	0.288	0.2187	124.26			
400.0	100.00	CO2	0.2500	0.6700	2.680	2.604	0.6511	126.77			
400.0	100.00	METHANE	0.0200	0.1500	7.500	6.464	0.1293	126.77			
400.0	100.00	N-BUTANE	0.7300	0.1800	0.247	0.301	0.2196	126.77			
400.0	100.00	CO2	0.0000	-0.0000	-0.000	2.398	0.0000	111.95			
400.0	100.00	METHANE	0.1220	0.8240	6.754	6.509	0.7941	111.95			
400.0	100.00	N-BUTANE	0.8780	0.1760	0.200	0.234	0.2059	111.95			
400.0	100.00	CO2	0.3000	0.8200	2.733	2.612	0.7835	127.99			
400.0	100.00	METHANE	0.0000	0.0000	0.000	6.413	0.0000	127.99			
400.0	100.00	N-BUTANE	0.7000	0.1800	0.257	0.309	0.2165	127.99			
800.0	100.00	CO2	0.1000	0.1740	1.740	1.255	0.1255	97.74			
800.0	100.00	METHANE	0.2230	0.7000	3.139	3.397	0.7576	97.74			
800.0	100.00	N-BUTANE	0.6770	0.1260	0.186	0.173	0.1169	97.74			
800.0	100.00	CO2	0.2000	0.3100	1.550	1.240	0.2480	95.80			
800.0	100.00	METHANE	0.1930	0.5630	2.917	3.343	0.6452	95.80			
800.0	100.00	N-BUTANE	0.6070	0.1270	0.209	0.176	0.1068	95.80			
800.0	100.00	CO2	0.3000	0.4380	1.460	1.242	0.3726	96.05			
800.0	100.00	METHANE	0.1600	0.4380	2.737	3.299	0.5278	96.05			
800.0	100.00	N-BUTANE	0.5400	0.1240	0.230	0.184	0.0996	96.05			

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL							BUB POINT	CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
800.0	100.00			CO2	0.4000	0.5350	1.337	1.246	0.4982	96.64
800.0	100.00			METHANE	0.1260	0.3450	2.738	3.251	0.4096	96.64
800.0	100.00			N-BUTANE	0.4740	0.1200	0.253	0.194	0.0922	96.64
800.0	100.00			CO2	0.5000	0.6410	1.282	1.241	0.6204	96.32
800.0	100.00			METHANE	0.0930	0.2460	2.645	3.190	0.2967	96.32
800.0	100.00			N-BUTANE	0.4070	0.1130	0.278	0.204	0.0829	96.32
BUBPT MORE THAN FORTY TRIALS ARE REQ.										
800.0	100.00			CO2	0.6000	0.7380	1.230	1.125	0.6752	112.47
800.0	100.00			METHANE	0.0550	0.1580	2.873	1.533	0.0843	112.47
800.0	100.00			N-BUTANE	0.3450	0.1040	0.301	0.697	0.2404	112.47
800.0	100.00			CO2	0.7000	0.8700	1.243	1.092	0.7646	108.40
800.0	100.00			METHANE	0.0140	0.0440	3.143	1.367	0.0191	108.40
800.0	100.00			N-BUTANE	0.2860	0.0860	0.301	0.756	0.2162	108.40
800.0	100.00			CO2	-0.0000	0.0000	0.000	1.263	-0.0000	98.95
800.0	100.00			METHANE	0.2540	0.8770	3.453	3.442	0.8744	98.95
800.0	100.00			N-BUTANE	0.7460	0.1230	0.165	0.168	0.1257	98.95
BUBPT MORE THAN FORTY TRIALS ARE REQ.										
800.0	100.00			CO2	0.7350	0.9200	1.252	1.084	0.7969	106.79
800.0	100.00			METHANE	0.0000	0.0000	0.000	1.334	0.0000	106.79
800.0	100.00			N-BUTANE	0.2650	0.0800	0.302	0.767	0.2031	106.79
1200.0	100.00			CO2	0.1000	0.1100	1.100	0.895	0.0895	80.54
1200.0	100.00			METHANE	0.3430	0.7730	2.254	2.371	0.8134	80.54
1200.0	100.00			N-BUTANE	0.5570	0.1170	0.210	0.174	0.0971	80.54
1200.0	100.00			CO2	0.2000	0.2200	1.100	0.930	0.1861	86.35
1200.0	100.00			METHANE	0.3030	0.6670	2.201	2.363	0.7160	86.35
1200.0	100.00			N-BUTANE	0.4970	0.1130	0.227	0.197	0.0979	86.35
1200.0	100.00			CO2	0.3000	0.3470	1.157	0.956	0.2868	90.47
1200.0	100.00			METHANE	0.2640	0.5430	2.057	2.338	0.6172	90.47
1200.0	100.00			N-BUTANE	0.4360	0.1100	0.252	0.220	0.0959	90.47
1200.0	100.00			CO2	0.4000	0.4400	1.100	0.974	0.3896	93.16
1200.0	100.00			METHANE	0.2260	0.4500	1.991	2.297	0.5190	93.16
1200.0	100.00			N-BUTANE	0.3740	0.1100	0.294	0.244	0.0914	93.16

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

DEW POINT

NEW CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)
400.0	400.0	100.00	100.00	CO2	0.0500	0.1280	2.560	2.809	0.0456	101.57
400.0	400.0	100.00	100.00	METHANE	0.1020	0.6960	6.824	6.344	0.1097	101.57
400.0	400.0	100.00	100.00	N-BUTANE	0.8480	0.1760	0.208	0.208	0.8448	101.57
400.0	400.0	100.00	100.00	CO2	0.1000	0.2600	2.600	2.853	0.0911	103.79
400.0	400.0	100.00	100.00	METHANE	0.0820	0.5610	6.841	6.368	0.0881	103.79
400.0	400.0	100.00	100.00	N-BUTANE	0.8180	0.1790	0.219	0.218	0.8208	103.79
400.0	400.0	100.00	100.00	CO2	0.1500	0.4000	2.667	2.879	0.1389	105.29
400.0	400.0	100.00	100.00	METHANE	0.0620	0.4200	6.774	6.374	0.0659	105.29
400.0	400.0	100.00	100.00	N-BUTANE	0.7880	0.1800	0.228	0.226	0.7953	105.29
400.0	400.0	100.00	100.00	CO2	0.2000	0.5380	2.690	2.895	0.1858	106.43
400.0	400.0	100.00	100.00	METHANE	0.0410	0.2820	6.878	6.369	0.0443	106.43
400.0	400.0	100.00	100.00	N-BUTANE	0.7590	0.1800	0.237	0.234	0.7699	106.43
400.0	400.0	100.00	100.00	CO2	0.2500	0.6700	2.680	2.908	0.2304	107.55
400.0	400.0	100.00	100.00	METHANE	0.0200	0.1500	7.500	6.357	0.0236	107.55
400.0	400.0	100.00	100.00	N-BUTANE	0.7300	0.1800	0.247	0.241	0.7460	107.55
400.0	400.0	100.00	100.00	CO2	0.0000	-0.0000	-0.000	2.790	-0.0000	100.60
400.0	400.0	100.00	100.00	METHANE	0.1220	0.8240	6.754	6.334	0.1301	100.60
400.0	400.0	100.00	100.00	N-BUTANE	0.8780	0.1760	0.200	0.202	0.8699	100.60
400.0	400.0	100.00	100.00	CO2	0.3000	0.8200	2.733	2.920	0.2808	108.86
400.0	400.0	100.00	100.00	METHANE	0.0000	0.0000	0.000	6.335	0.0000	108.86
400.0	400.0	100.00	100.00	N-BUTANE	0.7000	0.1800	0.257	0.250	0.7192	108.86
800.0	800.0	100.00	100.00	CO2	0.1000	0.1740	1.740	1.525	0.1141	101.80
800.0	800.0	100.00	100.00	METHANE	0.2230	0.7000	3.139	3.452	0.2028	101.80
800.0	800.0	100.00	100.00	N-BUTANE	0.6770	0.1260	0.186	0.184	0.6832	101.80
800.0	800.0	100.00	100.00	CO2	0.2000	0.3100	1.550	1.552	0.1998	104.36
800.0	800.0	100.00	100.00	METHANE	0.1930	0.5630	2.917	3.452	0.1631	104.36
800.0	800.0	100.00	100.00	N-BUTANE	0.6070	0.1270	0.209	0.199	0.6371	104.36
800.0	800.0	100.00	100.00	CO2	0.3000	0.4380	1.460	1.552	0.2822	104.53
800.0	800.0	100.00	100.00	METHANE	0.1600	0.4380	2.737	3.427	0.1278	104.53
800.0	800.0	100.00	100.00	N-BUTANE	0.5400	0.1240	0.230	0.210	0.5900	104.53

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL DEW POINT NEW CHAO-SEADER CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)
800.0	800.0	100.00		CO2	0.4000	0.5350	1.337	1.542	0.3469	103.73
800.0	800.0	100.00		METHANE	0.1260	0.3450	2.738	3.394	0.1016	103.73
800.0	800.0	100.00		N-BUTANE	0.4740	0.1200	0.253	0.218	0.5515	103.73
800.0	800.0	100.00		CO2	0.5000	0.6410	1.282	1.516	0.4228	101.45
800.0	800.0	100.00		METHANE	0.0930	0.2460	2.645	3.340	0.0736	101.45
800.0	800.0	100.00		N-BUTANE	0.4070	0.1130	0.278	0.224	0.5036	101.45
800.0	800.0	100.00		CO2	0.6000	0.7380	1.230	1.477	0.4996	97.94
800.0	800.0	100.00		METHANE	0.0550	0.1580	2.873	3.270	0.0483	97.94
800.0	800.0	100.00		N-BUTANE	0.3450	0.1040	0.301	0.230	0.4521	97.94
800.0	800.0	100.00		CO2	0.7000	0.8700	1.243	1.389	0.6265	89.67
800.0	800.0	100.00		METHANE	0.0140	0.0440	3.143	3.108	0.0142	89.67
800.0	800.0	100.00		N-BUTANE	0.2860	0.0860	0.301	0.239	0.3593	89.67
800.0	800.0	100.00		CO2	-0.0000	0.0000	0.000	1.476	0.0000	97.32
800.0	800.0	100.00		METHANE	0.2540	0.8770	3.453	3.430	0.2557	97.32
800.0	800.0	100.00		N-BUTANE	0.7460	0.1230	0.165	0.165	0.7443	97.32
800.0	800.0	100.00		CO2	0.7350	0.9200	1.252	1.345	0.6843	85.82
800.0	800.0	100.00		METHANE	0.0000	0.0000	0.000	2.981	0.0000	85.82
800.0	800.0	100.00		N-BUTANE	0.2650	0.0800	0.302	0.253	0.3158	85.82
1200.0	1200.0	100.00		CO2	0.1000	0.1100	1.100	1.119	0.0983	92.27
1200.0	1200.0	100.00		METHANE	0.3430	0.7730	2.254	2.439	0.3169	92.27
1200.0	1200.0	100.00		N-BUTANE	0.5570	0.1170	0.210	0.200	0.5847	92.27
1200.0	1200.0	100.00		CO2	0.2000	0.2200	1.100	1.114	0.1975	89.94
1200.0	1200.0	100.00		METHANE	0.3030	0.6670	2.201	2.400	0.2779	89.94
1200.0	1200.0	100.00		N-BUTANE	0.4970	0.1130	0.227	0.215	0.5246	89.94
1200.0	1200.0	100.00		CO2	0.3000	0.3470	1.157	1.104	0.3144	86.19
1200.0	1200.0	100.00		METHANE	0.2640	0.5430	2.057	2.319	0.2342	86.19
1200.0	1200.0	100.00		N-BUTANE	0.4360	0.1100	0.252	0.244	0.4514	86.19
DEWPT MORE THAN FOURTY TRIALS ARE REQ.										
1200.0	1200.0	100.00		CO2	0.4000	0.4400	1.100	1.024	0.4334	65.16
1200.0	1200.0	100.00		METHANE	0.2260	0.4500	1.991	1.972	0.2302	65.16
1200.0	1200.0	100.00		N-BUTANE	0.3740	0.1100	0.294	0.330	0.3364	65.16

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COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						BUB POINT		NEW CHAO-SEADER CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
400.0		100.00		CO2	0.0500	0.1280	2.560	2.960	0.1480	108.65
400.0		100.00		METHANE	0.1020	0.6960	6.824	6.450	0.6579	108.65
400.0		100.00		N-BUTANE	0.8480	0.1760	0.208	0.229	0.1941	108.65
400.0		100.00		CO2	0.1000	0.2600	2.600	2.904	0.2904	106.22
400.0		100.00		METHANE	0.0820	0.5610	6.841	6.401	0.5249	106.22
400.0		100.00		N-BUTANE	0.8180	0.1790	0.219	0.226	0.1848	106.22
400.0		100.00		CO2	0.1500	0.4000	2.667	2.859	0.4288	104.39
400.0		100.00		METHANE	0.0620	0.4200	6.774	6.358	0.3942	104.39
400.0		100.00		N-BUTANE	0.7880	0.1800	0.228	0.225	0.1770	104.39
400.0		100.00		CO2	0.2000	0.5380	2.690	2.840	0.5680	103.88
400.0		100.00		METHANE	0.0410	0.2820	6.878	6.329	0.2595	103.88
400.0		100.00		N-BUTANE	0.7590	0.1800	0.237	0.227	0.1725	103.88
400.0		100.00		CO2	0.2500	0.6700	2.680	2.823	0.7057	103.54
400.0		100.00		METHANE	0.0200	0.1500	7.500	6.298	0.1260	103.54
400.0		100.00		N-BUTANE	0.7300	0.1800	0.247	0.231	0.1683	103.54
400.0		100.00		CO2	0.0000	-0.0000	-0.000	3.034	0.0000	111.95
400.0		100.00		METHANE	0.1220	0.8240	6.754	6.509	0.7941	111.95
400.0		100.00		N-BUTANE	0.8780	0.1760	0.200	0.234	0.2059	111.95
UBPT MORE THAN FOURTY TRIALS ARE REQ.										
400.0		100.00		CO2	0.3000	0.8200	2.733	1.490	0.4470	121.81
400.0		100.00		METHANE	0.0000	0.0000	0.000	1.285	0.0000	121.81
400.0		100.00		N-BUTANE	0.7000	0.1800	0.257	0.790	0.5530	121.81
800.0		100.00		CO2	0.1000	0.1740	1.740	1.408	0.1408	90.12
800.0		100.00		METHANE	0.2230	0.7000	3.139	3.369	0.7513	90.12
800.0		100.00		N-BUTANE	0.6770	0.1260	0.186	0.159	0.1079	90.12
UBPT MORE THAN FOURTY TRIALS ARE REQ.										
800.0		100.00		CO2	0.2000	0.3100	1.550	1.342	0.2684	83.07
800.0		100.00		METHANE	0.1930	0.5630	2.917	3.306	0.6380	83.07
800.0		100.00		N-BUTANE	0.6070	0.1270	0.209	0.154	0.0936	83.07
UBPT MORE THAN FOURTY TRIALS ARE REQ.										
800.0		100.00		CO2	0.3000	0.4380	1.460	1.270	0.3808	96.58
800.0		100.00		METHANE	0.1600	0.4380	2.737	1.383	0.2212	96.58
800.0		100.00		N-BUTANE	0.5400	0.1240	0.230	0.737	0.3980	96.58

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL						BUB POINT	NEW CHAO-SEADER CONSTANTS			
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(Y)	CALC(T)
800.0		100.00		CO2	0.4000	0.5350	1.337	1.205	0.4821	79.78
800.0		100.00		METHANE	0.1260	0.3450	2.738	1.285	0.1619	79.78
800.0		100.00		N-BUTANE	0.4740	0.1200	0.253	0.751	0.3560	79.78
800.0		100.00		CO2	0.5000	0.6410	1.282	1.156	0.5780	65.10
800.0		100.00		METHANE	0.0930	0.2460	2.645	1.219	0.1134	65.10
800.0		100.00		N-BUTANE	0.4070	0.1130	0.278	0.758	0.3087	65.10
BUBPT MORE THAN FOURTY TRIALS ARE REQ.										
800.0		100.00		CO2	0.6000	0.7380	1.230	1.119	0.6717	53.36
800.0		100.00		METHANE	0.0550	0.1580	2.873	1.164	0.0640	53.36
800.0		100.00		N-BUTANE	0.3450	0.1040	0.301	0.766	0.2643	53.36
BUBPT MORE THAN FOURTY TRIALS ARE REQ.										
800.0		100.00		CO2	0.7000	0.8700	1.243	1.091	0.7634	43.15
800.0		100.00		METHANE	0.0140	0.0440	3.143	1.115	0.0156	43.15
800.0		100.00		N-BUTANE	0.2860	0.0860	0.301	0.773	0.2209	43.15
800.0		100.00		CO2	-0.0000	0.0000	0.000	1.492	-0.0000	98.95
800.0		100.00		METHANE	0.2540	0.8770	3.453	3.442	0.8744	98.95
800.0		100.00		N-BUTANE	0.7460	0.1230	0.165	0.168	0.1257	98.95
BUBPT MORE THAN FOURTY TRIALS ARE REQ.										
800.0		100.00		CO2	0.7350	0.9200	1.252	1.081	0.7949	39.54
800.0		100.00		METHANE	0.0000	0.0000	0.000	1.098	0.0000	39.54
800.0		100.00		N-BUTANE	0.2650	0.0800	0.302	0.774	0.2051	39.54
1200.0		100.00		CO2	0.1000	0.1100	1.100	0.998	0.0998	73.69
1200.0		100.00		METHANE	0.3430	0.7730	2.254	2.355	0.8079	73.69
1200.0		100.00		N-BUTANE	0.5570	0.1170	0.210	0.166	0.0923	73.69
1200.0		100.00		CO2	0.2000	0.2200	1.100	1.009	0.2018	73.69
1200.0		100.00		METHANE	0.3030	0.6670	2.201	2.336	0.7078	73.69
1200.0		100.00		N-BUTANE	0.4970	0.1130	0.227	0.182	0.0904	73.69
1200.0		100.00		CO2	0.3000	0.3470	1.157	1.120	0.3359	72.25
1200.0		100.00		METHANE	0.2640	0.5430	2.057	1.380	0.3642	72.25
1200.0		100.00		N-BUTANE	0.4360	0.1100	0.252	0.688	0.2999	72.25
BUBPT MORE THAN FOURTY TRIALS ARE REQ.										
1200.0		100.00		CO2	0.4000	0.4400	1.100	1.092	0.4367	61.99
1200.0		100.00		METHANE	0.2260	0.4500	1.991	1.307	0.2955	61.99
1200.0		100.00		N-BUTANE	0.3740	0.1100	0.294	0.716	0.2678	61.99

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL							DEW POINT		GRAYSON STREED CONSTANTS		
P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)	
400.0	400.0	100.00	100.00	CO2	0.0500	0.1280	2.560	2.303	0.0556	106.10	
400.0	400.0	100.00	100.00	METHANE	0.1020	0.6960	6.824	5.825	0.1195	106.10	
400.0	400.0	100.00	100.00	N-BUTANE	0.8480	0.1760	0.208	0.213	0.8249	106.10	
400.0	400.0	100.00	100.00	CO2	0.1000	0.2600	2.600	2.342	0.1110	109.14	
400.0	400.0	100.00	100.00	METHANE	0.0820	0.5610	6.841	5.843	0.0960	109.14	
400.0	400.0	100.00	100.00	N-BUTANE	0.8180	0.1790	0.219	0.226	0.7930	109.14	
400.0	400.0	100.00	100.00	CO2	0.1500	0.4000	2.667	2.370	0.1687	111.62	
400.0	400.0	100.00	100.00	METHANE	0.0620	0.4200	6.774	5.843	0.0719	111.62	
400.0	400.0	100.00	100.00	N-BUTANE	0.7880	0.1800	0.228	0.237	0.7594	111.62	
400.0	400.0	100.00	100.00	CO2	0.2000	0.5380	2.690	2.393	0.2249	113.79	
400.0	400.0	100.00	100.00	METHANE	0.0410	0.2820	6.878	5.833	0.0483	113.79	
400.0	400.0	100.00	100.00	N-BUTANE	0.7590	0.1800	0.237	0.248	0.7268	113.79	
400.0	400.0	100.00	100.00	CO2	0.2500	0.6700	2.680	2.413	0.2777	115.95	
400.0	400.0	100.00	100.00	METHANE	0.0200	0.1500	7.500	5.818	0.0258	115.95	
400.0	400.0	100.00	100.00	N-BUTANE	0.7300	0.1800	0.247	0.258	0.6964	115.95	
400.0	400.0	100.00	100.00	CO2	0.0000	-0.0000	-0.000	2.279	-0.0000	104.28	
400.0	400.0	100.00	100.00	METHANE	0.1220	0.8240	6.754	5.824	0.1415	104.28	
400.0	400.0	100.00	100.00	N-BUTANE	0.8780	0.1760	0.200	0.205	0.8585	104.28	
400.0	400.0	100.00	100.00	CO2	0.3000	0.8200	2.733	2.433	0.3370	118.52	
400.0	400.0	100.00	100.00	METHANE	0.0000	0.0000	0.000	5.796	0.0000	118.52	
400.0	400.0	100.00	100.00	N-BUTANE	0.7000	0.1800	0.257	0.271	0.6631	118.52	
800.0	800.0	100.00	100.00	CO2	0.1000	0.1740	1.740	1.417	0.1228	111.70	
800.0	800.0	100.00	100.00	METHANE	0.2230	0.7000	3.139	3.284	0.2132	111.70	
800.0	800.0	100.00	100.00	N-BUTANE	0.6770	0.1260	0.186	0.190	0.6641	111.70	
800.0	800.0	100.00	100.00	CO2	0.2000	0.3100	1.550	1.445	0.2145	115.43	
800.0	800.0	100.00	100.00	METHANE	0.1930	0.5630	2.917	3.274	0.1720	115.43	
800.0	800.0	100.00	100.00	N-BUTANE	0.6070	0.1270	0.209	0.207	0.6135	115.43	
800.0	800.0	100.00	100.00	CO2	0.3000	0.4380	1.460	1.455	0.3010	117.04	
800.0	800.0	100.00	100.00	METHANE	0.1600	0.4380	2.737	3.240	0.1352	117.04	
800.0	800.0	100.00	100.00	N-BUTANE	0.5400	0.1240	0.230	0.220	0.5638	117.04	

COMPARISON OF CHAO-SEADER K-RATIOS VS EXPERIMENTAL

DEW POINT

GRAYSON STREED CONSTANTS

P	PSIA	T	DEG F	COMPONENT	EXPT(X)	EXPT(Y)	EXPT(K)	CALC(K)	CALC(X)	CALC(T)
800.0	800.0	100.00	100.00	CO2	0.4000	0.5350	1.337	1.456	0.3675	117.47
800.0	800.0	100.00	100.00	METHANE	0.1260	0.3450	2.738	3.202	0.1078	117.47
800.0	800.0	100.00	100.00	N-BUTANE	0.4740	0.1200	0.253	0.229	0.5247	117.47
800.0	800.0	100.00	100.00	CO2	0.5000	0.6410	1.282	1.446	0.4431	116.67
800.0	800.0	100.00	100.00	METHANE	0.0930	0.2460	2.645	3.143	0.0783	116.67
800.0	800.0	100.00	100.00	N-BUTANE	0.4070	0.1130	0.278	0.236	0.4786	116.67
800.0	800.0	100.00	100.00	CO2	0.6000	0.7380	1.230	1.428	0.5168	114.66
800.0	800.0	100.00	100.00	METHANE	0.0550	0.1580	2.873	3.071	0.0515	114.66
800.0	800.0	100.00	100.00	N-BUTANE	0.3450	0.1040	0.301	0.241	0.4318	114.66
800.0	800.0	100.00	100.00	CO2	0.7000	0.8700	1.243	1.380	0.6305	108.80
800.0	800.0	100.00	100.00	METHANE	0.0140	0.0440	3.143	2.932	0.0150	108.80
800.0	800.0	100.00	100.00	N-BUTANE	0.2860	0.0860	0.301	0.243	0.3545	108.80
800.0	800.0	100.00	100.00	CO2	-0.0000	0.0000	0.000	1.371	0.0000	106.06
800.0	800.0	100.00	100.00	METHANE	0.2540	0.8770	3.453	3.276	0.2677	106.06
800.0	800.0	100.00	100.00	N-BUTANE	0.7460	0.1230	0.165	0.168	0.7323	106.06
800.0	800.0	100.00	100.00	CO2	0.7350	0.9200	1.252	1.364	0.6746	107.08
800.0	800.0	100.00	100.00	METHANE	0.0000	0.0000	0.000	2.876	0.0000	107.08
800.0	800.0	100.00	100.00	N-BUTANE	0.2650	0.0800	0.302	0.246	0.3254	107.08
1200.0	1200.0	100.00	100.00	CO2	0.1000	0.1100	1.100	1.118	0.0984	108.94
1200.0	1200.0	100.00	100.00	METHANE	0.3430	0.7730	2.254	2.416	0.3200	108.94
1200.0	1200.0	100.00	100.00	N-BUTANE	0.5570	0.1170	0.210	0.201	0.5817	108.94
1200.0	1200.0	100.00	100.00	CO2	0.2000	0.2200	1.100	1.124	0.1958	108.85
1200.0	1200.0	100.00	100.00	METHANE	0.3030	0.6670	2.201	2.375	0.2808	108.85
1200.0	1200.0	100.00	100.00	N-BUTANE	0.4970	0.1130	0.227	0.216	0.5234	108.85
1200.0	1200.0	100.00	100.00	CO2	0.3000	0.3470	1.157	1.134	0.3060	109.50
1200.0	1200.0	100.00	100.00	METHANE	0.2640	0.5430	2.057	2.319	0.2342	109.50
1200.0	1200.0	100.00	100.00	N-BUTANE	0.4360	0.1100	0.252	0.239	0.4599	109.50
1200.0	1200.0	100.00	100.00	CO2	0.4000	0.4400	1.100	1.145	0.3844	110.78
1200.0	1200.0	100.00	100.00	METHANE	0.2260	0.4500	1.991	2.265	0.1986	110.78
1200.0	1200.0	100.00	100.00	N-BUTANE	0.3740	0.1100	0.294	0.264	0.4170	110.78

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Erbar's Modification Of Cavett's Correlation For Hypothetical Components

It is desirable to predict the vapour liquid equilibrium data for complex hydrocarbon fractions, as these are usually encountered in stabilizer feeds. These complex hydrocarbon fractions can be handled by breaking them down into a series of hypothetical components. A correlation proposed by Cavett predicts the Chao-Seader Correlation data for these hypothetical components.

The minimum amount of information required for the use of Cavett's method, as modified by Erbar, is; either the molal average boiling point or the mean boiling point of the fraction, its API gravity and molecular weight. If the critical temperatures and pressures are known they can be also specified.

An outline of the procedure is as follows:

- (a) If the mean boiling point is not specified it is calculated from the molal average boiling point and the cubic average boiling point.

$$BP_{mn} = \frac{BP_{ca} + BP_{mla}}{2.0}$$

- (b) The specific gravity at 60°F is calculated by:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + ^\circ\text{API}}$$

The density at 25°C is: $d_{25} = 0.98907 \times \text{S.G. @ } 60^{\circ}\text{F}$

- (c) The liquid molal volume at 25°C is calculated by:

$$V_i^* = \frac{\text{molecular weight}}{d_{25}}$$

- (d) The Pseudo critical temperature and pressure for the hypothetical components can be calculated from the following equations:

$$T_c = a_1 + a_2T + a_3T^2 + a_4T^3 + a_5AT + a_6AT^2 + a_7A^2T^2$$

$$\log_{10}(P_c) = b_1 + b_2T + b_3T^2 + b_4T^3 + b_5AT + b_6AT^2 + b_7A^2T + b_8A^2T^2$$

- (e) The acentric factor W is calculated from Edmister's equation:

$$W_i = (3/7) \frac{(\log P_c / 14.7) - 1.0}{((T_b/T_c) - 1)}$$

- (f) The latent heat of vaporization is obtained from Kistiakowsky's equation (ii)

$$\frac{\Delta H_v}{T_b} = 7.58 + 4.571 \log T_b$$

T_b = mean average boiling point

and adjusted to 25°C by means of Watson's equation (ii)

$$\frac{\Delta H_{v25^{\circ}\text{C}}}{(\Delta H_v)_{\text{NBP}}} = \left(\frac{T_c - 537}{T_c - T_b} \right)^{0.38}$$

The solubility parameter is then calculated from the following equation:

$$\delta_i = \left(\frac{\Delta H - R^*T}{V_i^*} \right)^{\frac{1}{2}}$$

- (g) The constants for the ideal gas state enthalpy equation (a cubic equation) are calculated from the following equations: (iii)

$$H_A = MW (C_1 + C_2A + C_3A^2 + C_4A^3 + C_5K + C_6K^2 + C_7K^3 + C_{19}AK)$$

$$H_B = MW (C_8 + C_9A + C_{10}A^2 + C_{11}A^3 + C_{12}K + C_{13}K^2 + C_{14}K^3)$$

$$H_C = MW (C_{15} + C_{16}A)$$

$$H_D = MW (C_{17} + C_{18}A)$$

- (i) Edmister, W. C., "Applied Hydrocarbon Thermodynamics" Gulf Pub. Co., (1961).
- (ii) Prausnitz, J. M., W. C. Edmister and K. C. Chao, "Hydrocarbon Vapour-Liquid Equilibria and Solubility Parameter," paper presented at Atlantic City, New Jersey meeting, A. I. Ch. E. (March, 1957).
- (iii) Erbar, J. H., "NGPA K-ratio and H-value Computer Program", Oklahoma State University (1964).

Nomenclature

a	- equation constants.
A	- equation constants.
b	- equation constants.
BP_{ca}	- cubic average boiling point.
$BP_{m a}$	- molar average boiling point.
BP_{mn}	- mean average boiling point.
c	- equation constants.
d	- density.
HA, HB, HC, HD	- ideal gas enthalpy equation constants.
P_c	- critical pressure.
R^*	- gas constant.
T	- temperature.
T_b	- normal boiling point.
T_c	- critical temperature.
V_i^*	- molar volume.
δ_i	- solubility parameter.
ΔH_v	- molar heat of vaporization.
W_i	- acentric factor

Rigorous Computer ProgramsThiele-Geddes

Mainline

\$IBFTC COLUMN
(Thiele-Geddes
Program)

\$IBFTC

AINPUT

FEED
DISTIL
PHYS

FLASH
KVAL
KLVAL
HVAL

Subroutines

DEWPT
BUBPT
CFLOWR
COMP
TEMP
THETA

VLTEST
VPLLQP*
(VPLQP)*
AOUTPT

Modified Bergamini's Procedure

\$IBFTC COLUMN
(Bergamini Program)

\$IBFTC

BINPUT
FEED
DISTIL

BPHYS
FLASH
KVAL
KLVAL
HVAL

DEWPT
BUBPT

THETA
PSY
CTEMP
VLTEST

BOUTPT

* Either VPLQP (bottom up enthalpy balances) or VPLLQP (enthalpy balances from both ends) subroutine can be used but not both. VPLLQP is suggested as it is susceptible to a smaller roundoff error.

SOURCE STATEMENT

III-7

0 \$IBFTC COLUMN NODECK

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C *****
C
C     THE THIELE-GEDDES RIGOROUS MULTICOMPONENT COLUMN CALCULATING
C     PROCEEDURE INCLUDING THE CHAO-SEADER CURRELATION K-RATIO AND
C     ENTHALPY DATA CALCULATIONS ARE PROGRAMMED IN THIS PROGRAM.
C     THIS PROGRAM IS GENERAL FOR A SINGLE FEED AND WILL HANDLE EITHER
C     A PARTIAL OR A TOTAL CONDENSER.  SOME OF THE NECESSARY CONVERGENCE
C     FEATURES AND RESTRICTIONS ARE=
C
C         THETA CONVERGENCE METHOD
C     ALLOW EXTREME VARIATION OF 10 PERCENT FOR L-V PROFILES
C     AVERAGEING TEMP AND LIQUID-VAPOUR PROFILES AS CONVERGENCE FORCEING
C     10 DEG. MAX VARIATION IN T-PROFILE IS ALLOWED BEFORE L-V CORRECTIONS
C     ARE ATTEMPTED
C
C     *****
C
C ***** PROGRAM VARIABLES *****
C *** IMPORTANT VARIABLES IN BERGAMINI AND THIELE GEDDES PROGRAMS *****
C ***** DUMMY AND LESSER VARIABLES ARE NOT LISTED *****
C
C     A(*,*)      CONSTANTS FOR CHAO SEADER LIQ FUGACITY COEFF EQUATIONS
C     AA(*,*)     IDEAL GAS ENTHALPY EQUATION COEFFICIENTS
C     AAOB(*)     A**2/B CONSTANT FOR THE REDLICH-KWONG EQN OF STATE
C     ABF(*,*)    ABSORPTION FACTOR ( THIELE-GEDDES )
C     AK(*,*)     STAGE COMPONENT K RATIO
C     ALIQ(*)     STAGE COMP LIQ MOL RATE/PROD OR BOT RATE (THIELE-GEDDES)
C     ALIQO(*)    COMP LIQ MOL RATE/CONDEN PROD MOL RATE (THIELE-GEDDES)
C     ALP(*)      LIQUID FLOW RATE FROM PLATE PER MOLE OF FEED
C     ALP1(*)     STORED LIQUID PROFILE
C     ARK(*)      REDLICH KWONG COMPONENT MOLECULAR INTERACTION CONSTANTS
C     ASF(*,*)    STRIPPING FACTOR THIELE GEDDES METHOD ONLY
C     AVP(*)      VAPOUR FLOW RATE FROM PLATE PER MOLE FEED
C     AVP1(*)     STORED VAPOUR PROFILE
C     AVX         VAPOUR RATE LEAVING THE FEED STAGE (THIELE GEDDES)
C     AVX         VAPOUR RATE ABOVE FEED STAGE (BERGAMINI)
C     BBMIX(*)    B CONSTANT FOR REDLICH KWONG EQN OF STATE AT A STAGE
C     BI(*)       BOTTOMS COMPONENT MOLAR FLOW RATE
C     BIDI(*)     RATIO BOT COMP FLOW RATE/TOP COMP FLOW RATE
C     BMLA        MOLAR AVERAGE BOILING POINT DEGREES F
C     BOT         BOTTOM MOLAR FLOW RATE PER MOLE OF FEED
C     BPMNA       WEIGHT MEAN AVERAGE BOILING POINT DEGREES F
C     BPCA        CUBIC AVERAGE BOILING POINT DEGREES F
C     BRK(*)      REDLICH KWONG CRITICAL VOLUME INTERACTION CONSTANTS
C     BXI(*)      BOTTOMS COMPOSITION
C     CT(*)       CRITICAL TEMPERATURE DEGREES K
C     DDELMX(*)   WEIGHTED AVERAGE OF COMPONENT SOLUBILITY PARAMETERS
C     DELTA(*)    SOLUBILITY PARAMETER (CAL/ML)**0.5
C     DFRAC       FRACTION LIQUID IN CONDENSER
C     DI(*)       TOP PRODUCT COMPONENT MOLAR FLOW RATE
C     DIST        TOTAL PRODUCT FLOW RATE PER MOLE OF FEED
C     DQC         CONDENSER HEAT LOAD PER MOLE OF FEED
C     DQR         REBOILER HEAT LOAD PER MOLE FEED
C     DXI(*)      TOP PRODUCT COMPOSITION
C     FRAC        CALCULATED MOLE FRACTION LIQUID IN FEED

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SOURCE STATEMENT

III-8

C	FRC	READ IN MOLE FRACTION LIQUID IN FEED
C	FX(*)	OVERALL FEED COMPOSITION
C	GAM(*)	LIQUID COMPONENT ACTIVITY COEFFICIENT
C	GTHT	D-D SPEC FUNCTION FOR THETA CONVERGENCE
C	GTHTP	DERIVATIVE OF D-D SPEC FUNCTION FOR THETA CONVERGENCE
C	HDV	OVERHEAD VAPOUR ENTHALPY PER MOLE FEED
C	HLIQ	LIQUID ENTHALPY (DUMMY VARIABLE)
C	HVAP	VAPOUR ENTHALPY (DUMMY VARIABLE)
C	I	USUALLY REFERS TO COMPONENT NUMBER
C	L(*,*)	PLATE COMPONENT MOLAR LIQ FLOW RATES (BERGAMINI)
C	LO(*)	COMPONENT LIQ MOLAR FLOW RATE FROM CONDENSER (BERGAMINI)
C	LX(*)	LIQ COMP FLOW RATE FROM PLATE ABOVE FEED (BERGAMINI)
C	N	USUALLY REFERS TO PLATE NUMBER
C	NC	NUMBER OF REAL COMPONENTS
C	NCP	TOTAL NUMBER OF COMPONENTS REAL PLUS HYPOTHETICAL
C	NFP	FEED STAGE NUMBER
C	NHC	NUMBER OF HYPOTHETICAL COMPONENTS
C	NTP	NUMBER OF THEORETICAL STAGES
C	P	COLUMN PRESSURE
C	PC(*)	CRITICAL PRESSURE PSIA
C	PR	REDUCED PRESSURE
C	PSI(*,*)	SLOPE OF LOG K RATIO VS TEMP (BERGAMINI)
C	REFXR	REFLUX RATIO
C	SHBT	MOLAR ENTHALPY OF BOTTOMS
C	SHDI	MOLAR ENTHALPY OF BOTH CONDENSER OUTLET STREAMS
C	SHFI	FEED ENTHALPY
C	SHL(*)	LIQUID MOLAR STAGE ENTHALPIES (THIELE-GEDDES)
C	SHV(*)	VAPOUR MOLAR STAGE ENTHALPIES (THIELE-GEDDES)
C	T(*)	PLATE TEMPERATURE
C	TA(*)	ASSUMED TEMPERATURE (BERGAMINI)
C	TC(*)	CORRECTED TEMPERATURE (BERGAMINI)
C	TD	CONDENSER TEMPERATURE
C	TF	FEED TEMPERATURE
C	THET1	THETA IN THETA CONVERGENCE PROCEEDURE
C	TR	REDUCED TEMPERATURE
C	TT(*)	STORED STAGE TEMPERATURE PROFILE
C	TW	BOTTOMS TEMPERATURE
C	V(*)	VAPOUR COMP MOLAR FLOW RATE (DUMMY VARIABLE)(BERGAMINI)
C	VAP(*)	COMPONENT K RATIO (DUMMY VARIABLE)
C	VAPL(*)	LOG COMPONENT K-RATIO (DUMMY VARIABLE)
C	V1(*)	MOLAR VOLUME OF COMPONENT(*) IN THE LIQUID
C	W(*)	ACENTRIC FACTOR
C	X(*,*)	STAGE LIQUID MOLE FRACTIONS
C	XD(*)	PARTIAL CONDENSER LIQUID COMPOSITION
C	XFI(*)	FEED LIQUID COMPOSITION (SPLIT FEED)
C	XMT(*,*)	COMPONENT NAME
C	XR	RATIO OF BUBBLE POINT/ DEW POINT
C	XXWM	HYPOTHETICAL COMPONENT MOLECULAR WEIGHT
C	Y(*,*)	STAGE VAPOUR MOLE FRACTIONS
C	YD(*)	PARTIAL CONDENSER VAPOUR COMPOSITION
C	YFI(*)	FEED VAPOUR COMPOSITION (SPLIT FEED)
C	ZZ(*)	COMPRESSIBILITY FACTOR FOR VAPOUR AT A STAGE

***** FLAGS *****

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SOURCE STATEMENT

III-9

C JA1 HYDROGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA2 METHANE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA3 NITROGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA4 OXYGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA5 CARBON MONOXIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA6 CARBON DIOXIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JA7 HYDROGEN SULFIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C JX FEED FLAG (1=SL,2=SV,3=SPLIT FRC CON,4=SPLIT T CON)
C JXX CONDENSER FLAG (1=TOTAL, 2=PARTIAL CONDENSER)
C KKK(*) IDEAL K-RATIO SUBROUTINE FLAG
C KXN COUNTER IN THE MAIN PROGRAM
C KXX TEMP PROFILE FLAG CONTROLLING L-V PROFILE CALCULATIONS

C ***** PROGRAM ERROR MESSAGES *****

C *** ERROR 01 *** MORE THAN THIRTY TRIALS REQUIRED FOR FLASH
C CALLED FROM FLASH SUBROUTINE

C ABS(SUM MOLE FRAC IN LIQ-SUM MOLE FRAC IN THE VAP) AND OR
C ONE OR MORE OF THE MOLE FRACTIONS IN THE LIQUID PHASE
C DIFFERS FROM THE ONE PREVIOUSLY CALC BY 1.0E-04 AFTER 30
C TRIALS. THE LAST VALUES CALC ARE TAKEN.

C *** ERROR 02 *** MORE THAN THIRTY TRIALS ARE REQUIRED FOR Z CONVER
C ENCE

C CALLED FROM KVAL SUBROUTINE
C COMPRESSIBILITY FACTOR Z DIFFERS FROM THE ONE PREVIOUSLY
C CALCULATED BY MORE THAN 1.0E-04 IN ABSOLUTE VALUE AFTER
C THIRTY TRIALS. THE LAST CALCULATED VALUE IS TAKEN.

C *** ERROR 03 *** DEWPT MORE THAN THIRTY TRIALS ARE REQUIRED
C CALLED FROM DEWPT SUBROUTINE

C THE ABS(SUM MOLE FRACTION IN THE LIQ-1.) IS GREATER 1.0E-04
C AND OR ONE OR MORE OF THE COMPONENT MOLE FRACTIONS DIFFER FROM
C THE PREVIOUS CALCULATION BY 1.0E-04 AFTER THIRTY TRIALS
C THE VALUES FROM THE LAST CALC ARE TAKEN.

C *** ERROR 04 *** BUBPT MORE THAN THIRTY TRIALS ARE REQUIRED
C CALLED FROM BUBPT SUBROUTINE

C THE ABS(SUM MOLE FRACTION IN THE VAP-1.) IS GREATER 1.0E-04
C AND OR ONE OR MORE OF THE COMPONENT MOLE FRACTIONS DIFFER FROM
C THE PREVIOUS CALCULATION BY 1.0E-04 AFTER THIRTY TRIALS
C THE VALUES FROM THE LAST CALC ARE TAKEN.

C *** ERROR 05 *** MORE THAN THIRTY TRIALS ARE REQUIRED FOR DISTIL
C CALLED FROM SUBROUTINE DISTIL,PARTIAL CONDENSER CALCULATION

C ABS(SUM MOLE FRAC IN LIQ-1.) AND OR ONE OR MORE OF THE MOLE
C FRAC IN THE LIQ DIFFERS FROM THE PREVIOUS CALC BY MORE THAN
C 1.0E-04 AFTER 30 TRIALS. THE LAST CALC VALUES ARE TAKEN.

C *** ERROR 06 *** TEMP MORE THAN THIRTY TRIALS ARE REQUIRED
C CALLED FROM SUBROUTINE TEMP

C TEMPERATURE CORRECTION SUBROUTINE IN THE THIELE GEDDES METHOD.
C THE ABS(SUMY-1.) IS GREATER THAN 1.0E-04 IN THE BUBBLE POINT
C THE LAST CALCULATED TEMPERATURE IS TAKEN.

C *** ERROR 07 *** SPECIFICATION FOR D AND THETA NOT MET WITHIN 25
C TRIALS OF L-V PROFILES

C THE CALCULATIONS HAVE NOT CONVERGED TO THE SET SPECIFICATIONS
C CALLED FROM THE MAIN THIELE GEDDES OR BERGAMIN PROGRAMS
C AFTER 25 TRIALS AT CORRECTING THE LIQ-VAPOUR PROFILE.
C THESE ARE (D-D SPEC).LE.1.0E-04, ABS(THET1-1.0).LE.1.0E-03

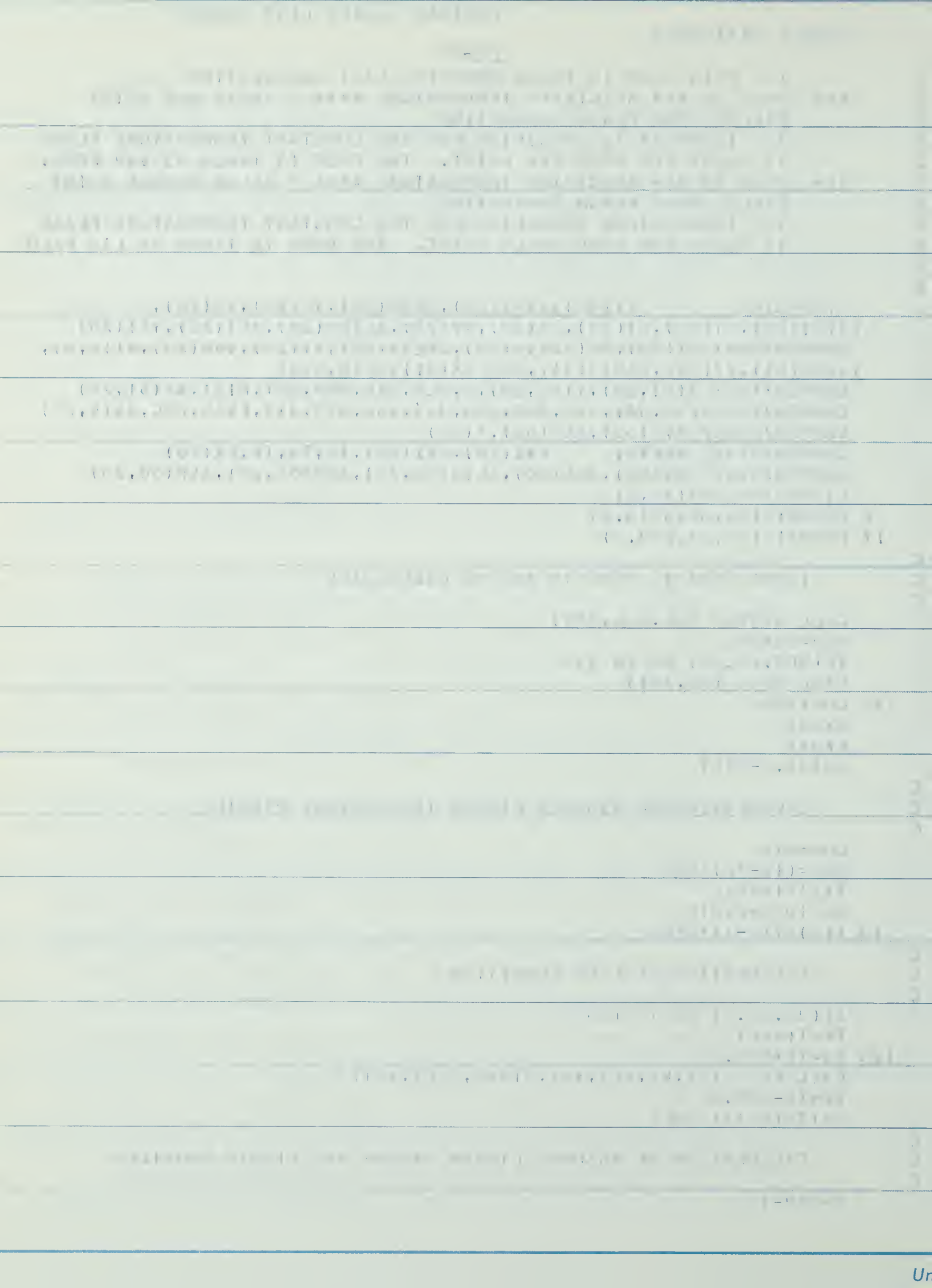
SOURCE STATEMENT

III-10

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C      THE PRINT OUT IS TAKEN FROM THE LAST CALCULATION
C      *** ERROR 08 *** SPECIFIED TEMPERATURE **** F ABOVE DEW POINT
C      CALLED FROM FLASH SUBROUTINE
C      THE TEMPERATURE SPECIFIED FOR THE CONSTANT TEMPERATURE FLASH
C      IS ABOVE THE FEED DEW POINT. THE FEED IS TAKEN AS VAP FEED.
C      *** ERROR 09 *** SPECIFIED TEMPERATURE **** F BELOW BUBBLE POINT
C      CALLED FROM FLASH SUBROUTINE
C      THE TEMPERATURE SPECIFIED FOR THE CONSTANT TEMPERATURE FLASH
C      IS BELOW THE FEED BUBBLE POINT. THE FEED IS TAKEN AS LIQ FEED
C
1      DIMENSION TT(50),AVP1(50),DLOR(20),YD(20),XD(20),
1BIDI(20),DI(20),BI(20),XX(20),YY(20),ALIQO(20),XFI(20),YFI(20)
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAQB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      COMMON/FOUR/ AVP(50),ALP(50),T(50)
6      COMMON/FIVE/ REF XR, BXI(20),DXI(20),TD,TW,TF,FX(20)
7      COMMON/SIX/ SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
10     DIMENSION XMT(20,2)
11     6 FORMAT (1X,6X,5E13.6)
12     17 FORMAT (1X,6X,E13.6)
C
C      INPUT DATA IS READ IN AND OR CALCULATED
C
13     CALL AINPUT (NC,NHC,XMT)
14     NCP=NC+NHC
15     IF(NCP.LE.NC) GO TO 130
20     CALL PHYS (NC,XMT)
21     130 CONTINUE
22     KXX=1
23     KXN=1
24     BOT=1.0-DIST
C
C      CALCULATION OF ASSUMED LINEAR TEMPERATURE PROFILE
C
25     CON=NTP
26     DEL=(TW-TD)/CON
27     T(1)=TD+DEL
30     DO 10 N=2,NTP
31     10 T(N)=T(N-1)+DEL
C
C      CALCULATION OF FEED CONDITION
C
33     IF(JX.EQ.4) GO TO 129
36     TF=T(NFP)
37     129 TX=TF+459.6
40     CALL FEED (TX,FX,XFI,YFI,NTP+2,SHFI,XMT)
41     TF=TX-459.6
42     WRITE(6,17) SHFI
C
C      CALCULATION OF ASSUMED LINEAR VAPOUR AND LIQUID PROFILES
C
43     M=NFP-1

```



SOURCE STATEMENT

III-11

```

44      DO 8 N=1,M
45      ALP(N)=REFXR*DIST
46      8 AVP(N)=(REFXR+1.)*DIST
50      M=NTP-1
51      DO 9 N=NFP,M
52      ALP(N)=ALP(NFP-1)+FRAC
53      9 AVP(N)=AVP(NFP-1)-(1.-FRAC)
55      AVP(NTP)=AVP(NFP-1)-(1.-FRAC)
56      ALP(NTP)=BOT
57      AVX=AVP(NFP)
60      AVP(NFP)=AVX+1.-FRAC

C
C      STORAGE OF V AND T PROFILES TO CHECK WITH NEWLY CALCULATED ONES
C

61      DO 469 N=1,NTP
62      469 AVP1(N)=AVP(N)
64      DO 415 N=1,NTP
65      415 TT(N)=T(N)

C
C      CALCULATION OF MOLAR LIQUID COMP FLOW RATE/TOP PRODUCT COMP FLOW
C      RATE RATIOS FOR THE ABSORPTION SECT AND MOLAR LIQUID COMP FLOW
C      RATE/BOTTOMS MOLAR COMP FLOW RATE RATIOS FOR THE STRIPPING SECT
C

67      DO 501 N=1,NTP
70      TX=T(N)+459.6
71      CALL KIVAL (N,IX,3)
72      DO 501 I=1,NCP
73      501 AK(N,I)=VAP(I)
76      GO TO (60,61),JXX
77      61 TX=TD+459.6
80      CALL KIVAL(NTP+1,IX,3)
81      DO 62 I=1,NCP
82      62 DLOR(I)=1./VAP(I)
84      GO TO 60
85      50 CONTINUE
86      DO 200 N=1,NTP
87      TX=T(N)+459.6
90      CALL KVAL (TX,N)
91      DO 200 I=1,NCP
92      AK(N,I)=VAP(I)
93      200 CONTINUE
96      60 GO TO (104,105),JXX
97      104 DO 107 I=1,NCP
98      107 ALIQO(I)=REFXR
100      GO TO 66
101      105 DO 108 I=1,NCP
102      108 ALIQO(I)=REFXR*DLOR(I)
103      66 CALL CFLOWR (ALIQO)

C
C      FEED PLATE MISMATCH INCORPORATING THETA METHOD OF CONVERGENCE
C      SETS THE CORRECTION FOR THE NEW ITERATION
C

127      SUMDI=0.
130      DO 109 I=1,NCP
131      ALQI=ALIQ(NFP,I)*(AK(NFP,I)*AVX/ALP(NFP))+1.0

```

1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 26

$$\frac{d}{dt} \left(\frac{\partial L}{\partial \dot{x}} \right) = \frac{\partial L}{\partial x}$$

1. The first part of the document is a list of names and addresses, which appears to be a directory or a list of subscribers. The names are written in a cursive script, and the addresses are listed below them.

2. The second part of the document is a list of names and addresses, which appears to be a directory or a list of subscribers. The names are written in a cursive script, and the addresses are listed below them.

3. The third part of the document is a list of names and addresses, which appears to be a directory or a list of subscribers. The names are written in a cursive script, and the addresses are listed below them.

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10. The tenth part of the document is a list of names and addresses, which appears to be a directory or a list of subscribers. The names are written in a cursive script, and the addresses are listed below them.

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

[illegible]

SN SOURCE STATEMENT

III-12

```

32      GO TO (121,122,123,123),JX
33      121 C1=1.
34          C2=0.
35          GO TO 120
36      122 C1=0.
37          C2=1.0
40          GO TO 120
41      123 C1=FRAC*XFI(I)/FX(I)
42          C2=(1.-FRAC)*YFI(I)/FX(I)
43      120 BIDI(I)=(ALIQ(NFP-1,I)+C1)/(ALQI-1.+C2)
44          DI(I)=FX(I)/(1.0+BIDI(I))
45      109 SUMDI=SUMDI+DI(I)
47          DEL1=(DIST-SUMDI)
50          WRITE(6,17) DEL1
    C      CONVERGENCE CRITERION
51          IF(KXN.LE.2) GO TO 15
54          IF(ABS(DEL1).LE.1.0E-04.AND.ABS(1.-THET1).LE.1.0E-03) GO TO 400
57      15 CONTINUE
    C      THETA CONVERGENCE
60          CALL THETA (THET1,FX,BIDI)
61      41 FORMAT(1X,6X,18H THETA CONVERGENCE=,F8.5)
62          WRITE(6,41) THET1
63          SUMDI=0.
64          SUMBI=0.
65          DO 113 I=1,NCP
66              DI(I)=FX(I)/(1.+THET1*BIDI(I))
67              BI(I)=THET1*BIDI(I)*DI(I)
70              SUMDI=SUMDI+DI(I)
71      113 SUMBI=SUMBI+BI(I)
73          DO 712 I=1,NCP
74              DXI(I)=DI(I)/SUMDI
75              XX(I)=DXI(I)
76      712 BXI(I)=BI(I)/SUMBI
    C
    C      CALCULATING NORMALIZED PLATE COMPOSITIONS
    C
00      CALL COMP (DI,BI)
    C
    C      CALCULATION OF CONDENSER CONDITION
    C
01          TD=TD+459.6
02          T(1)=T(1)+459.6
03          CALL DISTIL (TD,XX ,SHDI,HDX,NTP+1,YD,XD,REFXR,HDX,HDX,T(1))
04          TD=TD-459.6
05          T(1)=T(1)-459.6
06          DO 42 I=1,NCP
07      42 DLOR(I)=XD(I)/YD(I)
11          WRITE(6,17) HDV
12          WRITE(6,17) SHDI
13          WRITE (6,17) TD
    C
    C      BUBBLE POINT CALCULATION TO CORRECT TEMPERATURE PROFILE
    C
14          DO 309 N=1,NTP
15          TX=T(N)+459.6

```


SN SOURCE STATEMENT

III-13

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216 CALL TEMP (TX,N)
217 309 T(N)=TX-459.6
C
C CHECK TEMP PROFILE TO DECIDE IF L-V CORRECTIONS ARE TO BE MADE
C
21 KXX=0
22 DO 411 N=1,NTP
23 IF (ABS(TT(N)-T(N)).LE.10.) GO TO 411
26 KXX=1
27 411 CONTINUE
31 DO 412 N=1,NTP
32 T(N)=(T(N)+TT(N))/2.0
33 412 TT(N)=T(N)
35 IF (KXX.EQ.1) GO TO 50
C
C ENTHALPY BALANCES ARE USED TO CALCULATE NEW VAPOUR-LIQ PROFILES
C CONDENSER AND REBOILER HEAT LOADS ARE CALCULATED
C
40 DO 117 N=1,NTP
41 TX=T(N)+459.6
42 DO 900 I=1,NCP
43 900 XX(I)=X(N,I)
45 CALL HVAL (TX ,YY,XX,2,N)
46 SHL(N)=HLIQ
47 DO 901 I=1,NCP
50 901 YY(I)=Y(N,I)
52 CALL HVAL (TX ,YY,XX,1,N)
53 SHV(N)=HVAP
54 117 CONTINUE
56 CALL HVAL (TF+459.6,YFI,XX,1,NTP+2)
57 HH=HVAP
60 WRITE(6,17) HH
61 DO 915 I=1,NCP
62 915 YY(I)=Y(NFP,I)
64 CALL HVAL (T(NFP)+459.6,YY ,XX,1,NFP)
65 HHH=HVAP
66 WRITE(6,17) HHH
67 SHV(NFP)=((1.-FRAC)*HH+HHH*AVX)/(1.-FRAC+AVX)
70 DQC=(HDV-SHDI)*DIST*(REFXR+1.)
71 GO TO (30,31),JXX
72 30 DXD=SHDI
73 GO TO 32
74 31 DXD=HDY
75 32 DQR=DXD *DIST+SHL(NTP)*BOT-SHFI+DQC
76 WRITE(6,17) DQC
77 WRITE(6,17) DQR
80 CALL VPLQP(DQC,DQR,SHDI,SHFI,AVP1,HDX,HDY)
81 AVX=AVP(NFP)-1.0+FRAC
82 WRITE(6,14)
83 14 FORMAT(1X,20X,23HNEW TEMPERATURE PROFILE)
84 WRITE(6,6) (T(N),N=1,NTP)
85 WRITE(6,16)
86 16 FORMAT(1X,20X,18HNEW VAPOUR PROFILE)
87 WRITE(6,6) (AVP(N),N=1,NTP)
88 351 FORMAT (1X,16H*** ERROR 07 *** ,71HSPECIFICATIONS FOR D AND THETA N

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SN SOURCE STATEMENT

III-14

10T MET WITHIN 25 TRIALS OF L-V PROFILES)
 21 IF(KXN.LE.25) GO TO 350
 24 WRITE(6,351)
 25 GO TO 400
 26 350 CONTINUE
 27 KXN=KXN+1
 30 GO TO 50

C

C

C

31 400 CONTINUE
 32 AVP(NFP)=AVP(NFP)-1.+FRAC
 33 CALL ADUTP1 (DQC,DQR,XMT)
 34 CALL EXIT
 35 END

SOURCE STATEMENT

III-15

0 \$IBFTC COLUMN NODECK

```

C *****
C
C     THE BERGAMINI RIGOROUS MULTICOMPONENT COLUMN CALCULATING
C     PROCEEDURE INCLUDING THE CHAO-SEADER CORRELATION K-RATIO AND
C     ENTHALPY DATA CALCULATIONS ARE PROGRAMMED IN THIS PROGRAM.
C     THIS PROGRAM IS GENERAL FOR A SINGLE FEED AND WILL HANDLE EITHER
C     A PARTIAL OR A TOTAL CONDENSER.  SOME OF THE NECESSARY CONVERGENCE
C     FEATURES AND RESTRICTIONS ARE=
C
C         THETA CONVERGENCE METHOD
C     ALLOW EXTREME VARIATION OF 10 PERCENT FOR L-V PROFILES
C     AVERAGEING TEMP AND LIQUID-VAPOUR PROFILES AS CONVERGENCE FORCEING
C     10 DEG. MAX VARIATION IN T-PROFILE IS ALLOWED BEFORE L-V CORRECTIONS
C     ARE ATTEMPTED
C
C     *****
C ***** PROGRAM VARIABLES *****
C *** IMPORTANT VARIABLES IN BERGAMINI AND THIELE GEDDES PROGRAMS *****
C ***** DUMMY AND LESSER VARIABLES ARE NOT LISTED *****
C
C     A(*,*)      CONSTANTS FOR CHAO SEADER LIQ FUGACITY COEFF EQUATIONS
C     AA(*,*)     IDEAL GAS ENTHALPY EQUATION COEFFICIENTS
C     AAOB(*)     A**2/B CONSTANT FOR THE REDLICH-KWONG EQN OF STATE
C     ABF(*,*)    ABSORPTION FACTOR ( THIELE-GEDDES )
C     AK(*,*)     STAGE COMPONENT K RATIO
C     ALIQ(*)     STAGE COMP LIQ MOL RATE/PROD OR BOT RATE (THIELE-GEDDES)
C     ALIQO(*)    COMP LIQ MOL RATE/CONDEN PROD MOL RATE (THIELE-GEDDES)
C     ALP(*)      LIQUID FLOW RATE FROM PLATE PER MOLE OF FEED
C     ALP1(*)     STORED LIQUID PROFILE
C     ARK(*)      REDLICH KWONG COMPONENT MOLECULAR INTERACTION CONSTANTS
C     ASF(*,*)    STRIPPING FACTOR THIELE GEDDES METHOD ONLY
C     AVP(*)      VAPOUR FLOW RATE FROM PLATE PER MOLE FEED
C     AVP1(*)     STORED VAPOUR PROFILE
C     AVX         VAPOUR RATE LEAVING THE FEED STAGE (THIELE GEDDES)
C     AVX         VAPOUR RATE ABOVE FEED STAGE (BERGAMINI)
C     BBMIX(*)    B CONSTANT FOR REDLICH KWONG EQN OF STATE AT A STAGE
C     BI(*)       BOTTOMS COMPONENT MOLAR FLOW RATE
C     BIDI(*)     RATIO BOT COMP FLOW RATE/TOP COMP FLOW RATE
C     BMLA        MOLAR AVERAGE BOILING POINT DEGREES F
C     BOT         BOTTOM MOLAR FLOW RATE PER MOLE OF FEED
C     BPMNA       WEIGHT MEAN AVERAGE BOILING POINT DEGREES F
C     BPCA        CUBIC AVERAGE BOILING POINT DEGREES F
C     BRK(*)      REDLICH KWONG CRITICAL VOLUME INTERACTION CONSTANTS
C     BXI(*)      BOTTOMS COMPOSITION
C     CT(*)       CRITICAL TEMPERATURE DEGREES K
C     DDELMX(*)   WEIGHTED AVERAGE OF COMPONENT SOLUBILITY PARAMETERS
C     DELTA(*)    SOLUBILITY PARAMETER (CAL/ML)**0.5
C     DFRAC       FRACTION LIQUID IN CONDENSER
C     DI(*)       TOP PRODUCT COMPONENT MOLAR FLOW RATE
C     DIST        TOTAL PRODUCT FLOW RATE PER MOLE OF FEED
C     DQC         CONDENSER HEAT LOAD PER MOLE OF FEED
C     DQR         REBOILER HEAT LOAD PER MOLE FEED
C     DXI(*)      TOP PRODUCT COMPOSITION
C     FRAC        CALCULATED MOLE FRACTION LIQUID IN FEED

```


SOURCE STATEMENT

III-16

C	FRC	FEED IN MOLE FRACTION LIQUID IN FEED
C	FX(*)	OVERALL FEED COMPOSITION
C	GAM(*)	LIQUID COMPONENT ACTIVITY COEFFICIENT
C	GTHT	D-D SPEC FUNCTION FOR THETA CONVERGENCE
C	GTHTP	DERIVATIVE OF D-D SPEC FUNCTION FOR THETA CONVERGENCE
C	HDV	OVERHEAD VAPOUR ENTHALPY PER MOLE FEED
C	HLIQ	LIQUID ENTHALPY (DUMMY VARIABLE)
C	HVAP	VAPOUR ENTHALPY (DUMMY VARIABLE)
C	I	USUALLY REFERS TO COMPONENT NUMBER
C	L(*,*)	PLATE COMPONENT MOLAR LIQ FLOW RATES (BERGAMINI)
C	LO(*)	COMPONENT LIQ MOLAR FLOW RATE FROM CONDENSER (BERGAMINI)
C	LX(*)	LIQ COMP FLOW RATE FROM PLATE ABOVE FEED (BERGAMINI)
C	N	USUALLY REFERS TO PLATE NUMBER
C	NC	NUMBER OF REAL COMPONENTS
C	NCP	TOTAL NUMBER OF COMPONENTS REAL PLUS HYPOTHETICAL
C	NFP	FEED STAGE NUMBER
C	NHC	NUMBER OF HYPOTHETICAL COMPONENTS
C	NTP	NUMBER OF THEORETICAL STAGES
C	P	COLUMN PRESSURE
C	PC(*)	CRITICAL PRESSURE PSIA
C	PR	REDUCED PRESSURE
C	PSI(*,*)	SLOPE OF LOG K RATIO VS TEMP (BERGAMINI)
C	REFXR	REFLUX RATIO
C	SHBI	MOLAR ENTHALPY OF BOTTOMS
C	SHDI	MOLAR ENTHALPY OF BOTH CONDENSER OUTLET STREAMS
C	SHFI	FEED ENTHALPY
C	SHL(*)	LIQUID MOLAR STAGE ENTHALPIES (THIELE-GEDES)
C	SHV(*)	VAPOUR MOLAR STAGE ENTHALPIES (THIELE-GEDES)
C	T(*)	PLATE TEMPERATURE
C	TA(*)	ASSUMED TEMPERATURE (BERGAMINI)
C	TC(*)	CORRECTED TEMPERATURE (BERGAMINI)
C	TD	CONDENSER TEMPERATURE
C	TF	FEED TEMPERATURE
C	THET1	THETA IN THETA CONVERGENCE PROCEEDURE
C	TR	REDUCED TEMPERATURE
C	TT(*)	STORED STAGE TEMPERATURE PROFILE
C	TW	BOTTOMS TEMPERATURE
C	V(*)	VAPOUR COMP MOLAR FLOW RATE (DUMMY VARIABLE)(BERGAMINI)
C	VAP(*)	COMPONENT K RATIO (DUMMY VARIABLE)
C	VAPL(*)	LOG COMPONENT K-RATIO (DUMMY VARIABLE)
C	VL(*)	MOLAR VOLUME OF COMPONENT(*) IN THE LIQUID
C	w(*)	ACENTRIC FACTOR
C	X(*,*)	STAGE LIQUID MOLE FRACTIONS
C	XD(*)	PARTIAL CONDENSER LIQUID COMPOSITION
C	XFI(*)	FEED LIQUID COMPOSITION (SPLIT FEED)
C	XMT(*,*)	COMPONENT NAME
C	XR	RATIO OF BUBBLE POINT/ DEW POINT
C	XXWM	HYPOTHETICAL COMPONENT MOLECULAR WEIGHT
C	Y(*,*)	STAGE VAPOUR MOLE FRACTIONS
C	YD(*)	PARTIAL CONDENSER VAPOUR COMPOSITION
C	YFI(*)	FEED VAPOUR COMPOSITION (SPLIT FEED)
C	ZZ(*)	COMPRESSIBILITY FACTOR FOR VAPOUR AT A STAGE

***** FLAGS *****

SOURCE STATEMENT

III-17

```
C      JA1      HYDROGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA2      METHANE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA3      NITROGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA4      OXYGEN CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA5      CARBON MONOXIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA6      CARBON DIOXIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JA7      HYDROGEN SULFIDE CHAO-SEADER FUGACITY EQUATION CONSTANTS
C      JX       FEED FLAG (1=SL,2=SV,3=SPLIT FRC CON,4=SPLIT T CON)
C      JXX      CONDENSER FLAG (1=TOTAL, 2=PARTIAL CONDENSER)
C      KKK(*)    IDEAL K-RATIO SUBROUTINE FLAG
C      KXN      COUNTER IN THE MAIN PROGRAM
C      KXX      TEMP PROFILE FLAG CONTROLLING L-V PROFILE CALCULATIONS
C
C      ***** PROGRAM ERROR MESSAGES *****
C
C      *** ERROR 01 *** MORE THAN THIRTY TRIALS REQUIRED FOR FLASH
C      CALLED FROM FLASH SUBROUTINE
C      ABS(SUM MOLE FRAC IN LIQ-SUM MOLE FRAC IN THE VAP) AND OR
C      ONE OR MORE OF THE MOLE FRAC IN THE LIQ IN THE CONDENSER
C      DIFFERS FROM THE ONE PREVIOUSLY CALC BY 1.0E-04 AFTER 30
C      TRIALS. THE LAST VALUES CALC ARE TAKEN.
C      *** ERROR 02 *** MORE THAN THIRTY TRIALS ARE REQUIRED FOR Z CONVER
C      ENCE
C      CALLED FROM KVAL SUBROUTINE
C      COMPRESSIBILITY FACTOR Z DIFFERS FROM THE ONE PREVIOUSLY
C      CALCULATED BY MORE THAN 1.0E-04 IN ABSOLUTE VALUE AFTER
C      THIRTY TRIALS. THE LAST CALCULATED VALUE IS TAKEN.
C      *** ERROR 03 *** DEWPT MORE THAN THIRTY TRIALS ARE REQUIRED
C      CALLED FROM DEWPT SUBROUTINE
C      THE ABS(SUM MOLE FRACTION IN THE LIQ-1.) IS GREATER 1.0E-04
C      AND OR ONE OR MORE OF THE COMPONENT MOLE FRACTIONS DIFFER FROM
C      THE PREVIOUS CALCULATION BY 1.0E-04 AFTER THIRTY TRIALS
C      THE VALUES FROM THE LAST CALC ARE TAKEN.
C      *** ERROR 04 *** BUBPT MORE THAN THIRTY TRIALS ARE REQUIRED
C      CALLED FROM BUBPT SUBROUTINE
C      THE ABS(SUM MOLE FRACTION IN THE VAP-1.) IS GREATER 1.0E-04
C      AND OR ONE OR MORE OF THE COMPONENT MOLE FRACTIONS DIFFER FROM
C      THE PREVIOUS CALCULATION BY 1.0E-04 AFTER THIRTY TRIALS
C      THE VALUES FROM THE LAST CALC ARE TAKEN.
C      *** ERROR 05 *** MORE THAN THIRTY TRIALS ARE REQUIRED FOR DISTIL
C      CALLED FROM SUBROUTINE DISTIL,PARTIAL CONDENSER CALCULATION
C      ABS(SUM MOLE FRAC IN LIQ-1.) AND OR ONE OR MORE OF THE MOLE
C      FRAC IN THE LIQ DIFFERS FROM THE PREVIOUS CALC BY MORE THAN
C      1.0E-04 AFTER 30 TRIALS. THE LAST CALC VALUES ARE TAKEN.
C      *** ERROR 06 *** TEMP MORE THAN THIRTY TRIALS ARE REQUIRED
C      CALLED FROM SUBROUTINE TEMP
C      TEMPERATURE CORRECTION SUBROUTINE IN THE THIELE GEDDES METHOD.
C      THE ABS(SUMY-1.) IS GREATER THAN 1.0E-04 IN THE BUBBLE POINT
C      THE LAST CALCULATED TEMPERATURE IS TAKEN.
C      *** ERROR 07 *** SPECIFICATION FOR D AND THETA NOT MET WITHIN 25
C      TRIALS OF L-V PROFILES
C      CALLED FROM THE MAIN THIELE GEDDES OR BERGAMIN PROGRAMS
C      THE CALCULATIONS HAVE NOT CONVERGED TO THE SET SPECIFICATIONS
C      AFTER 25 TRIALS AT CORRECTING THE LIQ-VAPOUR PROFILE.
C      THESE ARE (D-D SPEC).LE.1.0E-04, ABS(THET1-1.0).LE.1.0E-03
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SN

SOURCE STATEMENT

III-18

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C      THE PRINT OUT IS TAKEN FROM THE LAST CALCULATION
C      *** ERROR 08 *** SPECIFIED TEMPERATURE **** F ABOVE DEW POINT
C      CALLED FROM FLASH SUBROUTINE
C      THE TEMPERATURE SPECIFIED FOR THE CONSTANT TEMPERATURE FLASH
C      IS ABOVE THE FEED DEW POINT.  THE FEED IS TAKEN AS VAP FEED.
C      *** ERROR 09 *** SPECIFIED TEMPERATURE **** F BELOW BUBBLE POINT
C      CALLED FROM FLASH SUBROUTINE
C      THE TEMPERATURE SPECIFIED FOR THE CONSTANT TEMPERATURE FLASH
C      IS BELOW THE FEED BUBBLE POINT.  THE FEED IS TAKEN AS LIQ FEED
C
1      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1      LAADB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
2      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
4      COMMON/FOUR/AVP(50),ALP(50),T(50)
5      COMMON/FIVE/ REFXR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
6      DIMENSION TA(5),V(20),BIDI(20),DI(20),BI(20),XX(20),YY(20),KKK(50)
7      DIMENSION XFI(20),YFI(20),XD(20),YD(20),PSI(51,20)
10     DIMENSION AVP1(50),ALP1(50),TT(50)
11     DIMENSION XMT(20,2)
12     REAL LO(20),L(50,20),LX(20)
13     6 FORMAT (1X,6X,5E13.6)
14     17 FORMAT (1X,6X,E13.6)
C
C      INPUT DATA IS READ IN AND OR CALCULATED
C
15     CALL BINPUT (NC,NHC,XMT)
16     NCP=NCP+NHC
17     IF(NCP.LE.NC) GO TO 130
22     CALL BPHYS (NC,XMT)
23     130 CONTINUE
24     KXX=1
25     KXN=1
26     BOT=1.0-DIST
27     DO 222 N=1,NTP
30     222 KKK(N)=1
32     DO 598 I=1,NCP
33     DI(I)=DIST *DXI(I)
34     598 BI(I)=BOT*BXI(I)
C
C      CALCULATION OF ASSUMED LINEAR TEMPERATURE PROFILE
C
36     CON=NTP
37     DEL=(TW-TD)/CON
40     TD=TD+459.6
41     T(1)=TD+DEL
42     DO 10 N=2,NTP
43     10 T(N)=T(N-1)+DEL
C
C      CALCULATION OF FEED CONDITION
C
45     IF(JX.EQ.4) GO TO 129
50     TF=T(NFP)
51     129 TX=TF

```

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

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[illegible]

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1

$$(\lambda_1 - \lambda_2) = 1.00$$
[illegible]

51

SOURCE STATEMENT

III-19

52

CALL FEED (TX,FX,XFI,YFI,NTP+2,SHFI,XMT)

53

TF=TX

54

WRITE(6,17) SHFI

C

C

CALCULATION OF ASSUMED LINEAR VAPOR AND LIQUID PROFILES

C

55

M=NFP-1

56

DO 8 N=1,M

57

ALP(N)=REFXR*DIST

60

8 AVP(N)=(REFXR+1.)*DIST

62

M=NTP-1

63

DO 9 N=NFP,M

64

ALP(N)=ALP(NFP-1)+FRAC

65

9 AVP(N)=AVP(NFP-1)-(1.-FRAC)

67

AVP(NTP)=AVP(NFP-1)-(1.-FRAC)

70

ALP(NTP)=BOT

C

C

STORAGE OF L-V-T PROFILES TO CHECK WITH NEWLY CALCULATED ONES

C

71

DO 131 N=1,NTP

72

ALP1(N)=ALP(N)

73

AVP1(N)=AVP(N)

74

131 TP(N)=T(N)

C

C

CALC OF CONDENSER CONDITION AND CONDENSER-REBOILER HEAT LOADS

C

76

GO TO (69,61),JXX

77

61 CALL KIVAL (NTP+1,TD,3)

80

DFRAC=REFXR/(REFXR+1.)

81

DO 62 I=1,NCP

82

YD(I)=DXI(I)

83

XD(I)=DXI(I)/VAP(I)

84

62 Y(1,I)=DFRAC*XD(I)+(1.-DFRAC)*YD(I)

86

GO TO 70

87

69 DO 777 I=1,NCP

90

777 Y(1,I)=DXI(I)

92

70 CALL KIVAL (1,T(1),1)

93

CALL KVAL (T(1),1)

94

DO 753 I=1,NCP

95

753 X(1,I)=Y(1,I)/VAP(I)

97

60 DO 75 I=1,NCP

98

75 XX(I)=DXI(I)

99

CALL DISTIL (TD,XX,SHDI,HDV,NTP+1,YD,XD,REFXR,HDX,HDY,T(1))

100

CALL BUBPT (BXI,T(NTP),NTP)

101

DO 938 I=1,NCP

102

938 XX(I)=X(NTP,I)

103

CALL HVAL (T(NTP),YY,XX,2,NTP)

104

SHBI=HLIQ

105

DQC=(HDV-SHDI)*DIST*(REFXR+1.)

106

GO TO (30,31),JXX

107

30 DXD=SHDI

108

GO TO 32

109

31 DXD=HDY

110

32 DQR=DXD*DIST+SHBI*(1.-DIST)-SHFI+DQC

111

WRITE(6,17) DQC

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SV SOURCE STATEMENT

III-20

40 WRITE(5,17) DQR
 41 GO TO(80,81),JXX
 42 80 HD=DIST*SHDI
 43 GO TO 82
 44 81 HD=DIST*HDY
 45 82 CONTINUE
 46 HB=SHBI*BOT

C
 C CALCULATING FROM BOTTOM UP COLUMN, PLATE BY PLATE, MASS BALANCES,
 C TEMPERATURE CORRECTIONS AND ENTHALPY BALANCES.
 C

47 DO 327 I=1,NCP
 50 327 L(NTP-1,I)=AVP(NTP)*Y(NTP,I)+BI(I)
 52 DO 714 I=1,NCP
 53 714 L(NTP,I)=BOT*BXI(I)
 55 MM=NTP
 56 KF=NTP-NFP
 57 DO 1000 NN=1,KF
 60 N=MM-NN
 61 K=1
 62 K1=1
 63 KK=1
 64 TA(K)=T(N)
 65 668 CONTINUE
 66 IF(K1.LE.2) GO TO 313
 71 IF(N.EQ.NFP) GO TO 313
 74 IF(KXX.EQ.1) GO TO 313
 77 DO 802 I=1,NCP
 80 802 YY(I)=Y(N,I)
 82 CALL HVAL (T(N),YY,XX,1,N)
 83 HV=HVAP
 84 CALL HVAL (T(N-1),YY,YY,2,N-1)
 85 HL=HLIQ
 86 CALL HVAL (T(N-1),YY,BI,2,N-1)
 87 HT=HLIQ
 90 AVP(N)=(HT-HB+DQR)/(HV-HL)
 91 CALL VLTEST (AVP,AVP1,N)
 92 ALP(N-1)=AVP(N)+BOT
 93 313 SUMY=0.
 94 K1=3
 95 SUMX=0.
 96 DO 314 I=1,NCP
 97 314 SUMX=SUMX+L(N,I)
 100 DO 803 I=1,NCP
 102 803 X(N,I)=L(N,I)/SUMX
 104 TX=T(N)
 105 IF(KKK(N).GT.2) GO TO 670
 106 CALL KIVAL (N,TX,2)
 107 KKK(N)=3
 108 670 CALL KVAL (TX,N)
 109 DO 672 I=1,NCP
 110 672 AK(K,I)=VAP(I)
 111 DO 671 I=1,NCP
 112 671 SUMY=SUMY+L(N,I)*AK(K,I)
 113 DO 316 I=1,NCP

SN

SOURCE STATEMENT

III-21

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42 316 Y(N,I)=L(N,1)*AK(K,I)/SUMY
44 IF(N.EQ.NFP) GO TO 972
47 DO 315 I=1,NCP
50 315 L(N-1,I)=AVP(N)*X(N,I)*AK(K,I)+BI(I)
52 GO TO 973
53 972 DO 974 I=1,NCP
54 974 LX(I)=AVP(NFP)*Y(N,I)+BI(I)
56 973 XR=SUMX/SUMY
57 IF(KK.GT.2)GO TO 317
62 CALL PSY (TA(K),K,N,PSI)
63 KK=3
64 317 CALL CTEMP (TA,TZ,K,N,XR,PSI)
65 IF(K.LT.3) GO TO 668
70 T(N)=TZ
71 1000 CONTINUE

C
C      CALCULATING DOWN THE COLUMN FROM TOP,PLATE BY PLATE, MASS BALANCES,
C      TEMPERATURE CORRECTIONS AND ENTHALPY BALANCES.
C

73 DO 2000 N=1,NFP
74 K=1
75 K1=1
76 KK=1
77 TA(K)=T(N)
80 667 CONTINUE
81 IF(N.EQ.NFP) GO TO 907
84 IF(N.EQ.1) GO TO 302
87 IF(K1.LE.2) GO TO 333
92 907 CONTINUE
93 IF(KXX.EQ.1) GO TO 911
96 DO 801 I=1,NCP
97 801 XX(I)=X(N-1,I)
98 CALL HVAL (T(N-1),YY,XX,2,N-1)
99 HL=HL IQ
100 IF(N.EQ.NFP) GO TO 909
103 GO TO 910
104 909 CALL HVAL (TF,XX,XX,1,N+2)
105 HH=HVAP
106 CALL HVAL (T(NFP),XX,XX,1,NFP)
107 HHH=HVAP
108 HV=(HH*(1.-FRAC)+HHH*AVP(NFP))/((1.-FRAC)+AVP(NFP))
109 CALL HVAL (TF,DI,XX,1,N+2)
110 HH=HVAP
111 CALL HVAL (T(NFP),DI,XX,1,NFP)
112 HHH=HVAP
113 HT=(HH*(1.-FRAC)+HHH*AVP(NFP))/((1.-FRAC)+AVP(NFP))
114 ALP(N-1)=(DQC+HD-HT)/(HV-HL)
115 AVX=ALP(N-1)+DIST
116 AVP(NFP)=AVX-1.+FRAC
117 GO TO 911
118 910 CONTINUE
119 CALL HVAL (T(N),XX,XX,1,N)
120 HV=HVAP
121 CALL HVAL (T(N),DI,XX,1,N)
122 HT=HVAP

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ISN SOURCE STATEMENT

III-22

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852     ALP(N-1)=(DGC+HD-HT)/(HV-HL)
853     CALL VLTEST (ALP,ALP1,N-1)
854     AVP(N)=ALP(N-1)+DIST
855 911 DO 713 I=1,NCP
856 713 L(N-1,I)=X(N-1,I)*ALP(N-1)
860     IF(N.EQ.NFP) GO TO 2000
863     GO TO 333
864 302 CONTINUE
865     IF (K.EQ.2) GO TO 663
870     AVP(1)=DIST*REFXR+DIST
871     GO TO (67,68),JXX
872 67 DO 754 I=1,NCP
873 754 LO(I)=DI(I)*REFXR
875     GO TO 755
876 68 DO 300 I=1,NCP
877 300 LO(I)=XD(I)*REFXR*DIST
901 755 DO 756 I=1,NCP
902 756 V(I)=LO(I)+DI(I)
904 333 SUMY=0.
905     K1=3
906     IF(N.EQ.1) GO TO 305
911     DO 335 I=1,NCP
912 335 V(I)=L(N-1,I)+DI(I)
914 305 DO 334 I=1,NCP
915 334 SUMY=SUMY+V(I)
917     DO 821 I=1,NCP
920 821 Y(N,I)=V(I)/SUMY
922 663 TX=TA(K)
923     IF(KKK(N).GT.2) GO TO 664
926     CALL KIVAL (N,TX,1)
927     KKK(N)=3
930 664 CALL KVAL (TX,N)
931     DO 665 I=1,NCP
932 665 AK(K,I)=VAP(I)
934     SUMX=0.
935     DO 666 I=1,NCP
936 666 SUMX=SUMX+V(I)/AK(K,I)
940     DO 336 I=1,NCP
941     X(N,I)=V(I)/AK(K,I)/SUMX
942 336 L(N,I)=X(N,I)*ALP(N)
944     XR=SUMX/SUMY
945     IF(KK.GT.2) GO TO 337
950     CALL PSY (TA(K),K,N,PSI)
951     KK=3
952 337 CALL CTEMP (TA,TZ,K,N,XR,PSI)
953     IF(K.LT.3) GO TO 667
956     T(N)=TZ
957 2000 CONTINUE
961     IF(KXX.EQ.1) GO TO 42
964     DO 411 I=1,NCP
965 411 YY(I)=Y(NTP,I)
967     CALL HVAL (T(NTP),YY,XX,1,NTP)
970     HHH=HVAP
971     DO 412 I=1,NCP
972 412 XX(I)=X(NTP,I)
```


SN

SOURCE STATEMENT

III-23

```

74      CALL HVAL (T(NTP),YY,XX,2,NTP)
75      HH=HLIQ
76      DO 413 I=1,NCP
77  413  XX(I)=X(NTP-1,I)
01      CALL HVAL (T(NTP-1),YY,XX,2,NTP-1)
02      H=HLIQ
03      AVP(NTP)=(BOT*(HH-H)-DQR)/(H-HHH)
04      ALP(NTP-1)=AVP(NTP)+BOT

C
C      FEED PLATE MISMATCH INCORPORATING THETA METHOD OF CONVERGENCE
C      SETS THE CORRECTION FOR THE NEXT ITERATION
C

05      42 SUMDI=0.
06      DO 109 I=1,NCP
07      GO TO (121,122,123,123),JX
10  121  C1=1.
11      C2=0.
12      GO TO 120
13  122  C1=0.
14      C2=1.0
15      GO TO 120
16  123  C1=FRAC*XF1(I)/FX(I)
17      C2=(1.-FRAC)*YF1(I)/FX(I)
20  120  BIDI(I)=(L(NTP-1,I)/DI(I) +C1)/(LX(I)/BI(I)-1.+C2)
21      DI(I)=FX(I)/(1.0+BIDI(I))
22  109  SUMDI=SUMDI+DI(I)
24      DEL1=(DIST-SUMDI)
25      WRITE(6,17) DEL1
C      CONVERGENCE CRITERION
26      IF(KXN.LE.2) GO TO 15
31      IF(ABS(DEL1).LE.1.0E-04.AND.ABS(1.-THET1).LE.1.0E-03) GO TO 400
34      15 CONTINUE
C      THETA CONVERGENCE
35      CALL THETA (THET1,FX,BIDI)
36      41 FORMAT(1X,6X,18H THETA CONVERGENCE=,F8.5)
37      WRITE(6,41) THET1
40      DO 113 I=1,NCP
41      DI(I)=FX(I)/(1.+THET1*BIDI(I))
42  113  BI(I)=THET1*BIDI(I)*DI(I)
44      SUMDI=0.
45      SUMBI=0.
46      DO 711 I=1,NCP
47      SUMDI=SUMDI+DI(I)
50  711  SUMBI=SUMBI+BI(I)
52      DO 712 I=1,NCP
53      DXI(I)=DI(I)/SUMDI
54  712  BXI(I)=BI(I)/SUMBI

C
C      CHECK I-PROFILE TO DECIDE IF L-V CORRECTIONS ARE TO BE MADE
C

56      KXX=0
57      DO 415 N=1,NTP
60      IF(ABS(TT(N)-T(N)).LE.10.) GO TO 415
63      KXX=1
64  415  CONTINUE

```

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SN SOURCE STATEMENT

III-24

```
66 DO 416 N=1,NTP
67 T(N)=(T(N)+TT(N))/2.0
70 416 TT(N)=T(N)
72 WRITE(6,14)
73 14 FORMAT(1X,20X,23HNEW TEMPERATURE PROFILE)
74 WRITE(6,6) (T(N),N=1,NTP)
01 WRITE(6,16)
02 16 FORMAT(1X,20X,18HNEW VAPOUR PROFILE)
03 WRITE(6,6) (AVP(N),N=1,NTP)
10 351 FORMAT (1X,16H*** ERROR 07 ***,71HSPECIFICATIONS FOR D AND THETA N
    10T MET WITHIN 25 TRIALS OF L-V PROFILES)
11 IF(KXN.LE.25) GO TO 350
14 WRITE(6,351)
15 GO TO 400
16 350 CONTINUE
17 IF(KXX.EQ.1) GO TO 60
22 KXN=KXN+1
23 GO TO 60

C
C PRINT OUT OF THE BERGAMINI CALCULATIONS
C

24 400 CONTINUE
25 DO 43 N=1,NTP
26 43 T(N)=T(N)-459.6
30 TD=TD-459.6
31 CALL BOUTPT (DQC,DQR,XMT)
32 CALL EXIT
33 END
```

()

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

Short Cut Design Programs With Rigorous Check CalculationsShort Cut + Thiele-Geddes

Mainline \$IBFTC COLUMN
 (Short Cut + Thiele-
 Geddes as subroutine)

\$IBFTC {
 SINPUT
 SRTCUT
 SOUTPT
 IN2PUT
 IN1TRP
 INTERP
 GOLDIT
 GEDDES } **
 Subroutines {
 SPHYS
 FEED
 FLASH
 DISTIL
 KVAL
 K1VAL
 HVAL
 DEWPT
 BUBPT
 CFLOWR } **
 COMP
 TEMP
 THEFA
 VPLLPQ
 VLTEST
 AOUTPT

Short Cut + Bergamini

\$IBFTC COLUMN
 (Short cut + Bergamini's
 calculational procedure
 as subroutine)

\$IBFTC {
 SINPUT
 SRTCUT
 SOUTPT
 IN2PUT
 IN1TRP
 INTERP
 GOLDIT } **
 BERGAM)
 SPHYS
 FEED
 FLASH
 DISTIL
 KVAL
 K1VAL
 HVAL
 DEWPT
 BUBPT } **
 THETA
 VLTEST
 PSY
 CTEMP
 BOUTPT

If the short cut design program alone is desired the (**) subroutines, which are used in the rigorous calculations only, can be removed.

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SN SOURCE STATEMENT

III-26

```

0 $IBFTC COLUMN NULIST,NODECK
C
C *****
C
C     THIS PROGRAM USES THE FENSKE-UNDERWOOD-MADDOX SHORT CUT METHOD
C     OF CALCULATING MULTI-COMPONENT DISTILLATION COLUMNS. THIS APPROX-
C     IMATE SOLUTION IS THEN USED AS A STARTING POINT FOR THE RIGOROUS
C     THIELE GEDDES OR BERGAMINI CALCULATIONS. THE RIGOROUS METHODS
C     MAY THEN BE USED TO OBTAIN THE DESIRED SPECIFICATIONS BY VARYING THE
C     THE OPERATING AND COLUMN SPECIFICATIONS.
C
C *****
C
1  COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
    IAAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
2  COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3  COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
4  COMMON/FOUR/ AVP(50),ALP(50),T(50)
5  COMMON/FIVE/ REFXR, BXI(20),DXI(20),TD,TW,TF,FX(20)
6  COMMON/SIX/ SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
7  DIMENSION YFI(20),XFI(20),DI(20),BI(20),FI(20)
10 DIMENSION XMT(20,2)
C
C     INPUT DATA IS READ IN AND OR CALCULATED
C
11 CALL SINPUT (NC,NHC,DI,BI,FI,P,RARM ,ILK,IHK,TF,XMT,ITERP)
C
C     CALCULATION OF FEED CONDITION
C
12 NCP=NC+NHC
13 IF(NCP.LE.NC) GO TO 129
16 CALL SPHYS (NC,XMT,FI,DI,BI)
17 129 TX=TF+459.6
20 FF=0.
21 DO 100 I=1,NCP
22 100 FF=FF+FI(I)
24 DO 101 I=1,NCP
25 DI(I)=DI(I)/FF
26 BI(I)=BI(I)/FF
27 101 FX(I)=FI(I)/FF
31 NTP=2
32 CALL FEED (TX,FX,XFI,YFI,NTP+2,SHFI,XMT)
33 TF=TX
34 CALL SRTCUT (DI,BI,XFI,YFI,SHFI,ILK,IHK,HXX,RARM,AN,SZ,DQC,DQR,ITE
    I RP,RM)
C
C     PRINT OUT OF SHORT CUT METHOD
C
35 CALL SOUTPT (DQC,DQR,AN,SZ,XMT,RM)
C
C     THIELE GEDDES RIGOROUS CALCULATION
C
36 CALL GEDDES (DI,BI,XFI,YFI,HXX,SHFI,DQC,DQR)
C
C     PRINT OUT OF THIELE GEDDES CALCULATIONS

```

Section 1: Introduction

The first part of the document discusses the importance of maintaining accurate records and the role of the committee in overseeing the process. It highlights the need for transparency and accountability in all actions taken.

Section 2: Objectives and Scope

This section outlines the primary objectives of the project, which include identifying key areas for improvement and implementing effective strategies. The scope of the work is defined to ensure that all relevant aspects are covered.

Section 3: Methodology

The methodology section describes the approach used to gather data and analyze the findings. It includes details on the selection of participants and the tools used for data collection.

Section 4: Results

The results section presents the findings of the study, organized into several key areas. Each area is supported by data and analysis, providing a clear picture of the current state of affairs.

Section 5: Discussion

In the discussion section, the findings are interpreted in the context of existing knowledge and research. The implications of the results are explored, and potential limitations of the study are acknowledged.

Section 6: Conclusion

The conclusion summarizes the main points of the document and provides a final assessment of the project's outcomes. It emphasizes the need for continued effort and collaboration to achieve the desired goals.

Section 7: Recommendations

The recommendations section offers practical advice based on the findings. It suggests specific actions that should be taken to address the identified issues and improve the overall process.

Section 8: Appendix

The appendix contains supplementary information that supports the main text. This includes additional data, charts, and references that provide further context and detail.

III-27

SN SOURCE STATEMENT

C

37 CALL AOUTPT (DQC,DQR,XMT)
40 CALL EXIT
41 END

SN

SOURCE STATEMENT

III-28

```

0  $IBFTC COLUMN  NOLIST,NODECK
C
C *****
C
C      THIS PROGRAM USES THE FENSKE-UNDERWOOD-MADDOX SHORT CUT METHOD
C      OF CALCULATING MULTI-COMPONENT DISTILLATION COLUMNS.  THIS APPROX-
C      IMATE SOLUTION IS THEN USED AS A STARTING POINT FOR THE RIGOROUS
C      THIELE GEDDES OR BERGAMINI CALCULATIONS.  THE RIGOROUS METHODS
C      MAY THEN BE USED TO OBTAIN THE DESIRED SPECIFICATIONS BY VARYING THE
C      THE OPERATING AND COLUMN SPECIFICATIONS.
C
C *****
C
1  COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
    IAAUB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
2  COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3  COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
4  COMMON/FOUR/ AVP(50),ALP(50),T(50)
5  COMMON/FIVE/ REFEX,      BXI(20),DXI(20),TD,TW,TF,FX(20)
6  COMMON/SIX/  SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
7  DIMENSION YFI(20),XFI(20),DI(20),BI(20),FI(20)
10 DIMENSION XMT(20,2)
C
C      INPUT DATA IS READ IN AND OR CALCULATED
C
11 CALL SINPUT (NC,NHC,DI,BI,FI,P,RARM ,ILK,IHK,TF,XMT,ITERP)
C
C      CALCULATION OF FEED CONDITION
C
12 NCP=NC+NHC
13 IF(NCP.LE.NC) GO TO 129
16 CALL SPHYS (NC,XMT,FI,DI,BI)
17 129 TX=TF+459.6
20 FF=0.
21 DO 100 I=1,NCP
22 100 FF=FF+FI(I)
24 DO 101 I=1,NCP
25 DI(I)=DI(I)/FF
26 BI(I)=BI(I)/FF
27 101 FX(I)=FI(I)/FF
31 NTP=2
32 CALL FEED (IX,FX,XFI,YFI,NTP+2,SHFI,XMT)
33 TF=TX
34 CALL SRTCUT (DI,BI,XFI,YFI,SHFI,ILK,IHK,HXX,RARM,AN,SZ,DQC,DQR,ITE
    IRP,RM)
C
C      PRINT OUT OF SHORT CUT METHOD
C
35 CALL SOUTPT (DQC,DQR,AN,SZ,XMT,RM)
C
C      BERGAMINI RIGOROUS CALCULATION
C
36 CALL BERGAM (DI,BI,XFI,YFI,HXX,SHFI,DQC,DQR)
C
C      PRINTOUT OF BERGAMINI CALCULATION PROCEDURE

```

SN SOURCE STATEMENT

III-29

C

37 CALL BOUTPT (DOC,DQR,XMT)
 40 CALL EXIT
 41 END

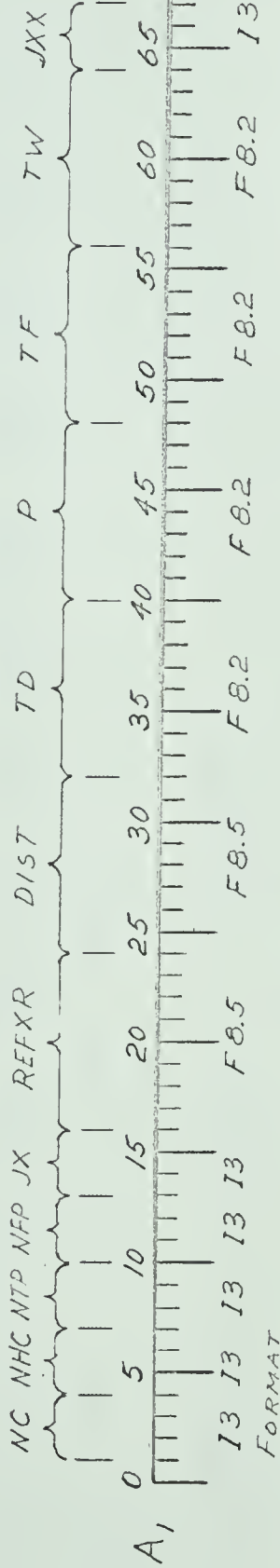
[Faint, illegible text spanning the main body of the page, likely bleed-through from the reverse side.]

INPUT DATA FOR RIGOROUS PROGRAMS

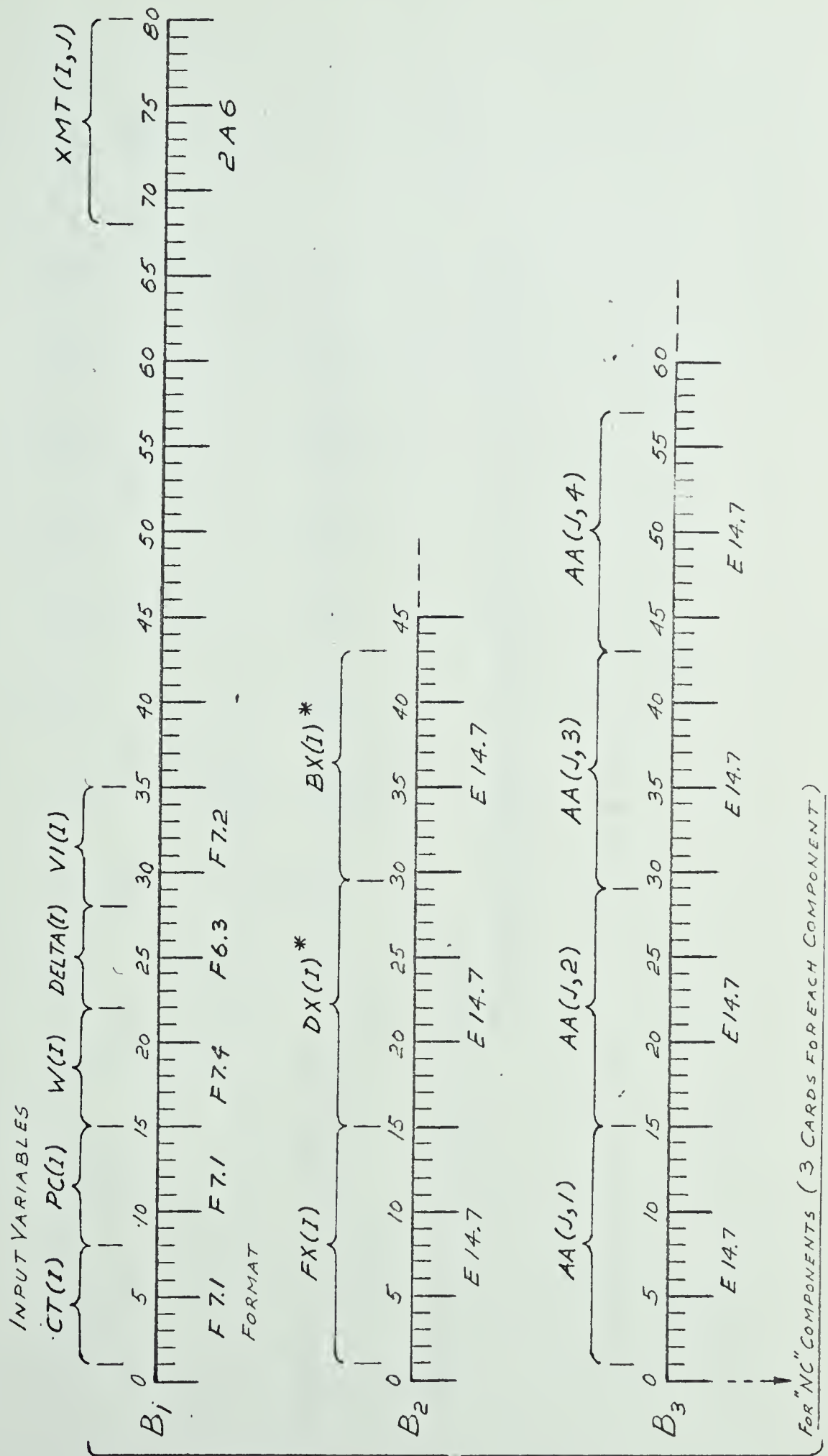
FOR SUBROUTINES \$1BFTC AINPUTOR \$1BFTC BINPUT

(i) PROBLEM DESCRIPTION (2 CARDS)

INPUT VARIABLES

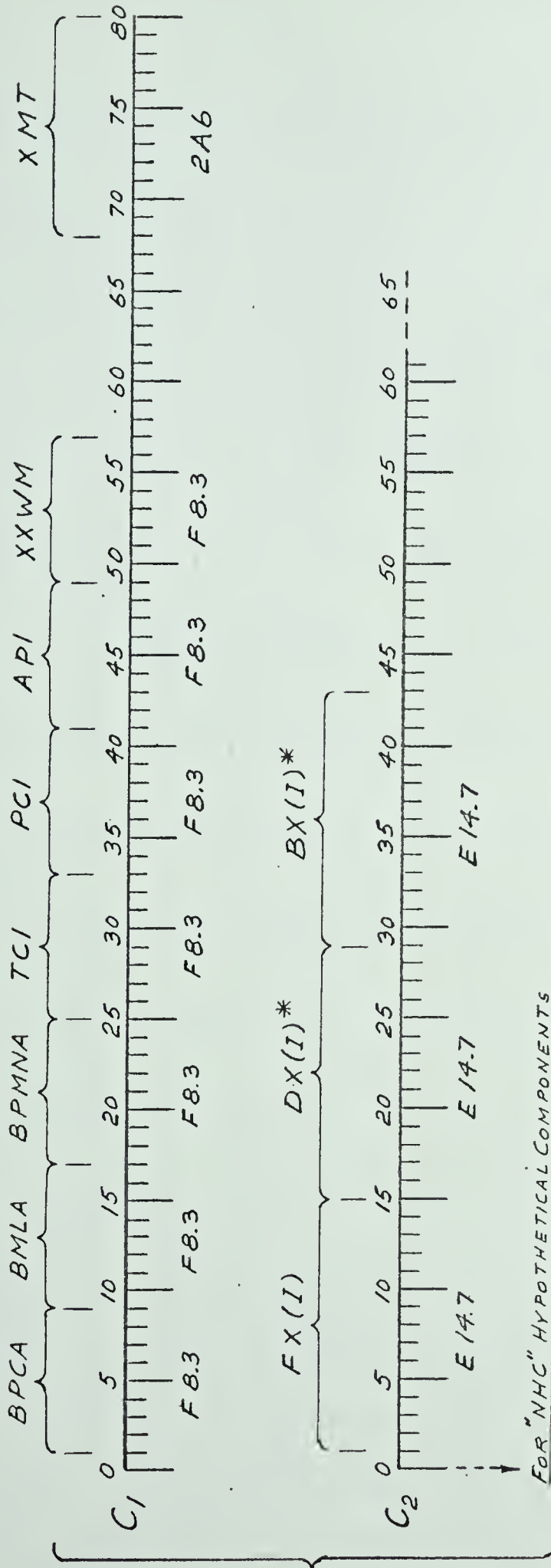


(ii) COMPONENT FEED COMPOSITION, CHAO-SEADER K-RATIO AND ENTHALPY DATA



* FOR MODIFIED BERGAMINI'S CALCULATIONAL PROCEDURE ONLY

(iii) Hypothetical Component Data



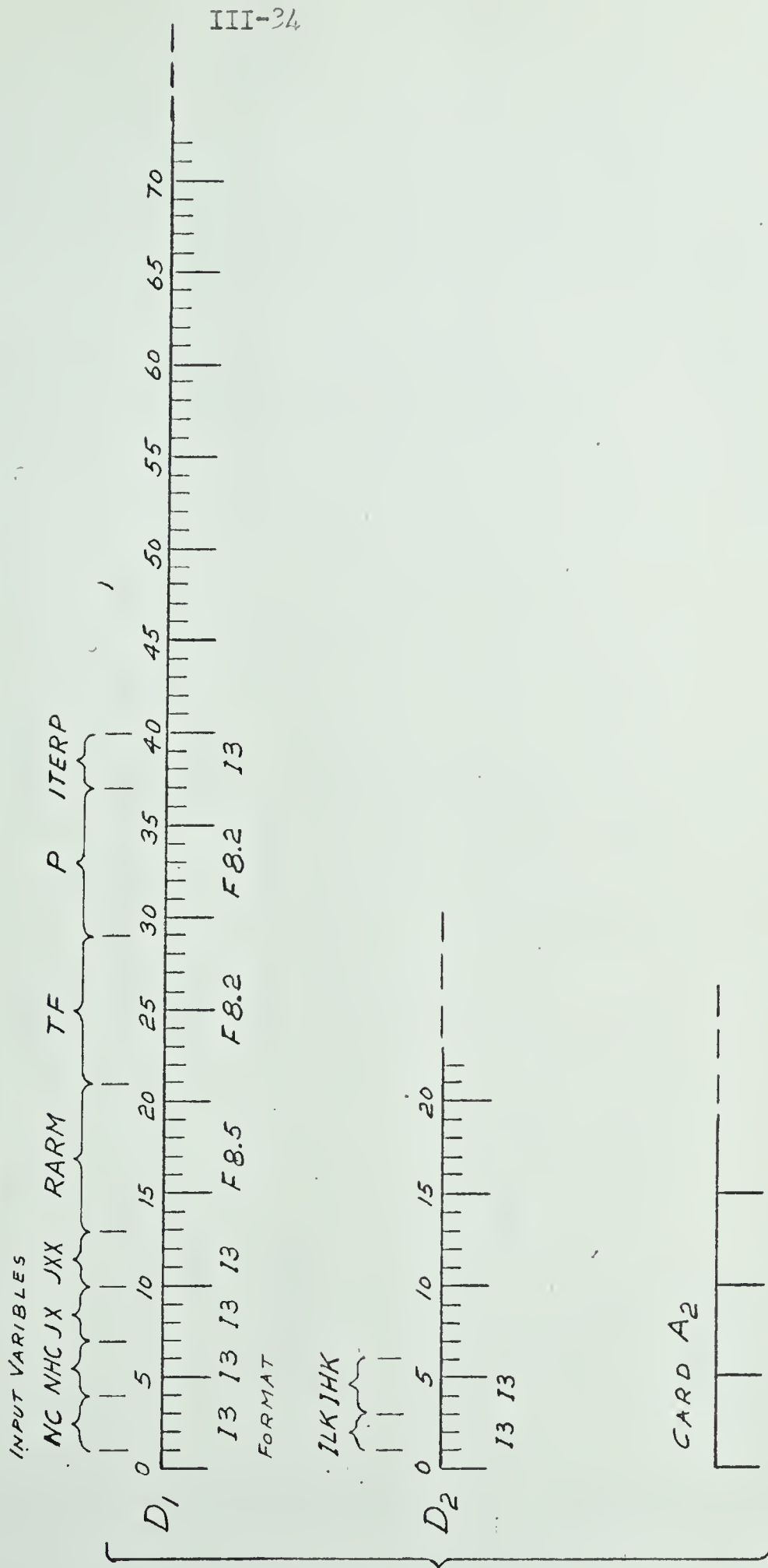
* FOR MODIFIED BERGAMINI'S CALCULATIONAL PROCEDURE ONLY

- (iv) Chao-Seader data is read in format 8F10.6 (twelve cards, two cards for each set of constants). They are read in, as shown in the sample input data, so that each set corresponds to the flags J11, J12.....J47.

III-23

INPUT DATA FOR SHORT CUT PROGRAM \$ 1BFTC SINPUT

(i) PROGRAM DESCRIPTION (3 CARDS)



- (iv) Chao-Seader data is read in, in format 8F10.6 (twelve cards, two cards for each set of constants). They are read in, as shown in the sample input data, so that each set of constants corresponds to the flags JA1, JA2JA7.
- (v) Erbar and Maddox Charts are read in, in the form of three dimensional 21 point grid as shown with sample input data.

| | | | | | | | | | | | |
|-------------|------------|-----------|-------------|-----------|------------|--------------|---------|-------|-------|-------|--|
| -30.0608746 | .1402053 | 41.263222 | -27.3030125 | .7102545 | 0.30828431 | -0.679105113 | .15544 | | | | |
| 0.0 | .089562849 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | |
| 0.058121 | -2.6491906 | .5742714 | -1.4647525 | .71734788 | -9.7215791 | .4272540 | -1.5024 | | | | |
| 0.33859029 | -.2667848 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |
| 0.550 | 0.600 | 0.650 | 0.700 | 0.750 | 0.800 | 0.850 | 0.900 | 0.950 | 1.000 | 0.000 | |
| 0.000 | 0.008 | 0.020 | 0.039 | 0.064 | 0.092 | 0.125 | 0.161 | 0.199 | 0.239 | 0.283 | |
| 0.326 | 0.372 | 0.418 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.050 | 0.057 | 0.066 | 0.076 | 0.088 | 0.105 | 0.128 | 0.161 | 0.199 | 0.239 | 0.283 | |
| 0.326 | 0.372 | 0.418 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.100 | 0.100 | 0.112 | 0.120 | 0.130 | 0.143 | 0.159 | 0.178 | 0.203 | 0.240 | 0.283 | |
| 0.326 | 0.372 | 0.418 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.150 | 0.155 | 0.161 | 0.168 | 0.177 | 0.187 | 0.199 | 0.213 | 0.230 | 0.253 | 0.284 | |
| 0.227 | 0.372 | 0.418 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.200 | 0.205 | 0.211 | 0.218 | 0.226 | 0.235 | 0.246 | 0.257 | 0.271 | 0.288 | 0.308 | |
| 0.335 | 0.373 | 0.418 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.250 | 0.253 | 0.259 | 0.267 | 0.274 | 0.283 | 0.293 | 0.303 | 0.316 | 0.331 | 0.349 | |
| 0.269 | 0.394 | 0.424 | 0.466 | 0.517 | 0.574 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.300 | 0.303 | 0.308 | 0.314 | 0.321 | 0.327 | 0.334 | 0.343 | 0.354 | 0.367 | 0.382 | |
| 0.401 | 0.422 | 0.448 | 0.479 | 0.519 | 0.575 | 0.641 | 0.730 | 0.850 | 1.000 | 0.000 | |
| 0.350 | 0.352 | 0.356 | 0.361 | 0.367 | 0.373 | 0.380 | 0.389 | 0.399 | 0.411 | 0.425 | |
| 0.441 | 0.461 | 0.483 | 0.510 | 0.544 | 0.589 | 0.650 | 0.731 | 0.850 | 1.000 | 0.000 | |
| 0.400 | 0.402 | 0.407 | 0.410 | 0.414 | 0.419 | 0.425 | 0.432 | 0.441 | 0.452 | 0.466 | |
| 0.482 | 0.502 | 0.525 | 0.552 | 0.584 | 0.629 | 0.691 | 0.772 | 0.875 | 1.000 | 0.000 | |
| 0.450 | 0.452 | 0.455 | 0.458 | 0.461 | 0.465 | 0.470 | 0.478 | 0.487 | 0.498 | 0.511 | |
| 0.528 | 0.547 | 0.570 | 0.597 | 0.630 | 0.677 | 0.736 | 0.810 | 0.898 | 1.000 | 0.000 | |
| 0.500 | 0.501 | 0.504 | 0.507 | 0.510 | 0.515 | 0.520 | 0.527 | 0.534 | 0.544 | 0.557 | |
| 0.572 | 0.591 | 0.614 | 0.640 | 0.674 | 0.722 | 0.780 | 0.847 | 0.919 | 1.000 | 0.000 | |
| 0.550 | 0.551 | 0.554 | 0.557 | 0.561 | 0.565 | 0.570 | 0.576 | 0.584 | 0.595 | 0.607 | |
| 0.624 | 0.643 | 0.666 | 0.693 | 0.729 | 0.772 | 0.822 | 0.877 | 0.937 | 1.000 | 0.000 | |
| 0.600 | 0.601 | 0.603 | 0.606 | 0.609 | 0.614 | 0.619 | 0.625 | 0.633 | 0.643 | 0.656 | |
| 0.671 | 0.690 | 0.712 | 0.738 | 0.771 | 0.809 | 0.852 | 0.899 | 0.948 | 1.000 | 0.000 | |
| 0.650 | 0.651 | 0.653 | 0.656 | 0.659 | 0.664 | 0.669 | 0.678 | 0.685 | 0.694 | 0.703 | |
| 0.717 | 0.731 | 0.751 | 0.775 | 0.806 | 0.840 | 0.877 | 0.916 | 0.956 | 1.000 | 0.000 | |
| 0.700 | 0.701 | 0.703 | 0.706 | 0.709 | 0.713 | 0.718 | 0.723 | 0.730 | 0.738 | 0.748 | |
| 0.758 | 0.771 | 0.789 | 0.810 | 0.837 | 0.865 | 0.896 | 0.928 | 0.963 | 1.000 | 0.000 | |
| 0.750 | 0.751 | 0.753 | 0.756 | 0.759 | 0.762 | 0.767 | 0.770 | 0.777 | 0.783 | 0.792 | |
| 0.801 | 0.812 | 0.827 | 0.844 | 0.864 | 0.887 | 0.912 | 0.941 | 0.970 | 1.000 | 0.000 | |
| 0.800 | 0.801 | 0.802 | 0.804 | 0.807 | 0.810 | 0.814 | 0.819 | 0.823 | 0.829 | 0.834 | |
| 0.842 | 0.851 | 0.863 | 0.875 | 0.890 | 0.908 | 0.929 | 0.950 | 0.975 | 1.000 | 0.000 | |
| 0.850 | 0.851 | 0.852 | 0.854 | 0.857 | 0.859 | 0.862 | 0.866 | 0.869 | 0.873 | 0.879 | |
| 0.884 | 0.891 | 0.900 | 0.909 | 0.920 | 0.932 | 0.947 | 0.965 | 0.981 | 1.000 | 0.000 | |
| 0.900 | 0.901 | 0.902 | 0.903 | 0.904 | 0.905 | 0.907 | 0.909 | 0.910 | 0.914 | 0.919 | |
| 0.923 | 0.928 | 0.933 | 0.940 | 0.947 | 0.955 | 0.965 | 0.975 | 0.987 | 1.000 | 0.000 | |
| 0.950 | 0.951 | 0.952 | 0.953 | 0.954 | 0.955 | 0.956 | 0.957 | 0.958 | 0.960 | 0.962 | |
| 0.964 | 0.966 | 0.969 | 0.972 | 0.975 | 0.979 | 0.983 | 0.988 | 0.994 | 1.000 | 0.000 | |
| 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | |
| 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |
| 0.550 | 0.600 | 0.650 | 0.700 | 0.750 | 0.800 | 0.850 | 0.900 | 0.950 | 1.000 | 0.000 | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |
| 0.550 | 0.600 | 0.650 | 0.700 | 0.750 | 0.800 | 0.850 | 0.900 | 0.950 | 1.000 | 0.000 | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |
| 0.550 | 0.600 | 0.650 | 0.700 | 0.750 | 0.800 | 0.850 | 0.900 | 0.950 | 1.000 | 0.000 | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |
| 0.550 | 0.600 | 0.650 | 0.700 | 0.750 | 0.800 | 0.850 | 0.900 | 0.950 | 1.000 | 0.000 | |
| 0.000 | 0.050 | 0.100 | 0.150 | 0.200 | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | |

Input Variables

| | |
|---------|---|
| AI(J,I) | Constants for the ideal gas enthalpy equations. |
| AG | air gravity. |
| FI(I) | top product component "i" flow rate (lb. moles/unit time). |
| IBP | mean average boiling point ($^{\circ}\text{F}$). |
| ICB | - Cubic average boiling point ($^{\circ}\text{F}$). |
| ILB | molar average boiling point ($^{\circ}\text{F}$). |
| IX(I) | - Bottoms composition of component "i" (mole fraction). |
| TC(I) | - critical temperature ($^{\circ}\text{R}$). |
| VI | van der Waals parameter $\left(\frac{\text{cal}}{\text{ml}}\right)^{1/2}$. |
| DI(I) | Distillate product component "i" flow rate (lb. moles/unit time). |
| DR | Distillate rate (lb. mole/lb. mole feed). |
| DL(I) | Distillate liquid composition of component "i" (mole fraction). |
| FI(F) | Feed rate of component "i" $\left(\frac{\text{lb. moles}}{\text{unit time}}\right)$ |
| FL | Fraction liquid in a partially vaporized feed. |
| FX(I) | Feed composition of component "i" (mole fraction). |
| KEY | key component number. |
| KEY2 | key component number. |
| LL | 1 = linear interpolation for Edler and Maddox Charts, 1-linear; 2 = logarithmic. |
| HS | Hydrogen (H ₂ -Seader liquid fugacity equation constants' control character (component number of H ₂ is written). |

| | |
|-------|--|
| JA2 | - Methane Chao-Seader liquid fugacity equation constants' control character. |
| JA3 | - Nitrogen Chao-Seader liquid fugacity equation constants' control character. |
| JA4 | - Oxygen Chao-Seader liquid fugacity equation constants' control character. |
| JA5 | - Carbon Monoxide Chao-Seader liquid fugacity equation constants' control character. |
| JA6 | - Carbon Dioxide Chao-Seader liquid fugacity equation constants' control character. |
| JA7 | - Hydrogen Sulfide Chao-Seader liquid fugacity equation constants' control character. |
| JX | - Feed type specifying character, 1-saturated liquid, 2-saturated vapour, 3-split feed constant fraction liquid, 4-split feed at a constant temperature. |
| JXX | - Condenser type, 1-total condenser, 2-partial condenser. |
| NC | - Number of real components. |
| NFP | - Feed stage number. |
| NHC | - Number of hypothetical components. |
| NTP | - Total number of theoretical stages. |
| P | - Column pressure psia. |
| PC(I) | - Critical pressure of component "i" ($^{\circ}\text{R}$). |
| PC1 | - Critical pressure for a hypothetical component (psia). |
| REFXR | - Reflux ratio. |
| RAFM | - Ratio of reflux to the minimum reflux. |
| TD | - Distillate temperature ($^{\circ}\text{F}$). |
| TCL | - Critical temperature for a hypothetical component ($^{\circ}\text{R}$). |
| TF | - Feed temperature ($^{\circ}\text{F}$). |

- TW - Bottoms temperature ($^{\circ}\text{F}$).
- VL(I) - Molar volume of component "i" (mls/gm mole).
- W(I) - Component "i" acentric factor.
- XMF(I,J) - Component name.
- XXWM - Equivalent molecular weight for a hypothetical component.

TABLE III-I

CHAO SEADER COEFFICIENTS FOR THE COMPONENT LIQUID FUGACITY COEFFICIENT EQUATIONS

| | <u>Generalized*</u> | <u>Methane</u> | <u>Hydrogen</u> |
|-----------------|---------------------|----------------|-----------------|
| A ₁ | 5.75748 | 2.43840 | 1.96718 |
| A ₂ | -3.01761 | -2.24550 | 1.02972 |
| A ₃ | -4.98500 | -0.34084 | -0.054009 |
| A ₄ | 2.02299 | 0.00212 | 0.0005288 |
| A ₅ | 0.0 | -0.00223 | 0.0 |
| A ₆ | 0.08427 | 0.10486 | 0.008585 |
| A ₇ | 0.26667 | -0.03691 | 0.0 |
| A ₈ | -0.31138 | 0.0 | 0.0 |
| A ₉ | -0.02655 | 0.0 | 0.0 |
| A ₁₀ | 0.02883 | 0.0 | 0.0 |
| A ₁₁ | -4.23893 | 0.0 | 0.0 |
| A ₁₂ | 8.65808 | 0.0 | 0.0 |
| A ₁₃ | -1.22060 | 0.0 | 0.0 |
| A ₁₄ | -3.15224 | 0.0 | 0.0 |
| A ₁₅ | -0.025 | 0.0 | 0.0 |

* For Generalized Case:

Constants A₁ to A₁₁ are for "Simple Fluid".

Constants A₁₂ to A₁₅ are for "Departure from Simple Fluid".

TABLE III-II

CONSTANTS A_1 TO A_{15} FOR THE COMPONENT LIQUID FUGACITY COEFFICIENT EQUATIONS

| | <u>Generalized*</u> | <u>Methane</u> | <u>Hydrogen</u> |
|----------|---------------------|----------------|-----------------|
| A_1 | 2.05133 | 1.36822 | 1.50709 |
| A_2 | -2.10899 | -1.54831 | 2.74283 |
| A_3 | 0.0 | 0.0 | -0.02110 |
| A_4 | -0.19396 | 0.02889 | 0.00011 |
| A_5 | 0.02282 | -0.01076 | 0.0 |
| A_6 | 0.08852 | 0.10486 | 0.008585 |
| A_7 | 0.0 | -0.02529 | 0.0 |
| A_8 | -0.00872 | 0.0 | 0.0 |
| A_9 | -0.00353 | 0.0 | 0.0 |
| A_{10} | 0.00203 | 0.0 | 0.0 |
| A_{11} | -4.23893 | 0.0 | 0.0 |
| A_{12} | 8.65808 | 0.0 | 0.0 |
| A_{13} | -1.22060 | 0.0 | 0.0 |
| A_{14} | -3.15224 | 0.0 | 0.0 |
| A_{15} | -0.025 | 0.0 | 0.0 |

* For Generalized Case

Constants A_1 to A_{11} are for "Simple Fluids".

Constants A_{12} to A_{15} are for "Departure From Simple Fluid".

TABLE III-III

COEFFICIENTS FOR THE RIGBIAN LIQUID FUGACITY COEFFICIENT EQUATIONS FOR
 H_2 , H_2S , AND CO_2 , DEVELOPED BY J. H. ERBAR AND W. C. EDMISTER

| | <u>N_2</u> | <u>CO_2</u> | <u>H_2S</u> |
|-----|-------------------------|--------------------------|--------------------------|
| A1 | 2.7365534 | -30.060874 | 3.0581210 |
| A2 | -1.9818310 | 6.1409853 | -2.6491906 |
| A3 | -0.51487289 | 45.263229 | 0.37457945 |
| A4 | 0.042470988 | -27.303012 | -1.4647096 |
| A5 | -0.002814385 | 5.9152545 | 0.45734766 |
| A6 | -0.02947496 | 0.36838431 | -0.95721679 |
| A7 | 0.021495843 | -0.67916811 | 1.4272646 |
| A8 | 0.0 | 0.15546365 | -0.50242238 |
| A9 | 0.0 | 0.0 | 0.33859029 |
| A10 | 0.0 | 0.089562849 | -0.26678483 |
| A11 | 0.0 | 0.0 | 0.0 |
| A12 | 0.0 | 0.0 | 0.0 |
| A13 | 0.0 | 0.0 | 0.0 |
| A14 | 0.0 | 0.0 | 0.0 |
| A15 | 0.0 | 0.0 | 0.0 |

TABLE IV (a)

DATA FOR THE CHAO-SEADER CORRELATION

| | $T_c^{\circ R}$ | $P_{c,psia}$ | W_i | $s_i \left(\frac{Cal}{ml} \right)^{\frac{1}{2}}$ | $V_i^* \left(\frac{ml}{gm \text{ mole}} \right)$ |
|-------------------------------|-----------------|--------------|--------|---|---|
| N ₂ | 227.16 | 492.3 | .0206 | 4.440 | 53.0 |
| H ₂ S | 672.48 | 1306.5 | .0868 | 8.80 | 43.1 |
| CO ₂ | 547.56 | 1071.3 | .1768 | 7.120 | 44.0 |
| C ₁ | 343.9 | 673.1 | 0.0 | 5.68 | 52.0 |
| C ₂ H ₄ | 509.5 | 742.1 | 0.0949 | 6.08 | 61.0 |
| C ₂ | 550.5 | 709.8 | 0.1064 | 6.05 | 68.0 |
| C ₃ H ₆ | 657.2 | 667.0 | 0.1451 | 6.43 | 79.0 |
| C ₃ | 665.9 | 617.4 | 0.1538 | 6.40 | 84.0 |
| i-C ₄ | 734.7 | 529.1 | 0.1825 | 6.73 | 105.5 |
| n-C ₄ | 765.3 | 550.7 | 0.1953 | 6.73 | 101.4 |
| i-C ₅ | 829.8 | 483.0 | 0.2104 | 7.021 | 117.4 |
| n-C ₅ | 845.6 | 489.5 | 0.2387 | 7.021 | 116.1 |
| C ₆ | 914.2 | 440.0 | 0.2972 | 7.266 | 131.6 |
| C ₇ | 972.3 | 396.8 | 0.3403 | 7.430 | 147.5 |
| C ₈ | 1024.9 | 362.1 | 0.3992 | 7.551 | 163.5 |
| C ₉ | 1073.0 | 332.0 | 0.4439 | 7.649 | 179.6 |
| C ₁₀ | 1114.0 | 304.0 | 0.4869 | 7.721 | 196.0 |

TABLE IV (b)

IDEAL GAS ENTHALPY EQUATION COEFFICIENTS

| | <u>HA</u> | <u>HB</u> | <u>HC</u> | <u>HD</u> |
|-------------------------------|--------------------------|--------------------------|----------------------------|----------------------------|
| H ₂ | .3192124x10 ⁴ | .6956438x10 | -.3103818x10 ⁻⁴ | .2350028x10 ⁻⁶ |
| H ₂ S | .3659210x10 ⁴ | .8033766x10 | .6508904x10 ⁻³ | .3250902x10 ⁻⁶ |
| CO ₂ | .3357740x10 ⁴ | .8440110x10 | .3040541x10 ⁻² | -.7897689x10 ⁻⁶ |
| C ₁ | .3683894x10 ⁴ | .7880800x10 | .3505719x10 ⁻² | .2446472x10 ⁻⁶ |
| C ₂ H ₄ | .3791992x10 ⁴ | .9144806x10 | .7819394x10 ⁻² | -.1522679x10 ⁻⁵ |
| C ₂ | .4220126x10 ⁴ | .1120242x10 ² | .8938123x10 ⁻² | -.8066164x10 ⁻⁶ |
| C ₃ H ₆ | .4714762x10 ⁴ | .1350214x10 | .1146875x10 ⁻¹ | -.1797251x10 ⁻⁵ |
| C ₃ | .5068633x10 ⁴ | .1510799x10 ² | .1540639x10 ⁻¹ | -.2938696x10 ⁻⁵ |
| i-C ₄ | .6023067x10 ⁴ | .1999786x10 ² | .2044134x10 ⁻¹ | -.4146112x10 ⁻⁵ |
| n-C ₄ | .6654675x10 ⁴ | .2054464x10 ² | .1865250x10 ⁻¹ | -.3016738x10 ⁻⁵ |
| i-C ₅ | .7475643x10 ⁴ | .2465428x10 ² | .2446248x10 ⁻¹ | -.4437345x10 ⁻⁵ |
| n-C ₅ | .8039759x10 ⁴ | .2518989x10 ² | .2348587x10 ⁻¹ | -.4174458x10 ⁻⁵ |
| C ₆ | .9475028x10 ⁴ | .2952267x10 ² | .2914070x10 ⁻¹ | -.5911897x10 ⁻⁵ |
| C ₇ | .1056589x10 ⁵ | .3331526x10 ² | .3278746x10 ⁻¹ | -.6696126x10 ⁻⁵ |
| C ₈ | .1226219x10 ⁵ | .3899065x10 ² | .3841118x10 ⁻¹ | -.7945704x10 ⁻⁵ |
| C ₉ | .1366069x10 ⁵ | .4373618x10 ² | .4301726x10 ⁻¹ | -.8954763x10 ⁻⁵ |
| C ₁₀ | .1505435x10 ⁵ | .4848591x10 ² | .4756158x10 ⁻¹ | -.9858597x10 ⁻⁵ |

III-48

RIGOROUS PROGRAM
(Thiele-Geddes)

SAMPLE COMPUTER OUTPUT
PROBLEM 7

OBJECT PROGRAM IS BEING ENTERED INTO STORAGE.

FEED CONDITION

FLASH TEMP= 322.482 F FRACTION LIQUID= 0.82355999E 00

| COMPONENT | MF | FLASH LIQUID | MF | FLASH VAPOUR |
|-----------|----|----------------|----|----------------|
| H2S | | 0.34156329E-01 | | 0.16248451E 00 |
| CO2 | | 0.28032174E-02 | | 0.23856975E-01 |
| METHANE | | 0.88057368E-02 | | 0.10666446E 00 |
| ETHANE | | 0.70334184E-02 | | 0.48968992E-01 |
| PROPANE | | 0.32359133E-01 | | 0.10226642E 00 |
| I-BUTANE | | 0.28730188E-01 | | 0.55876445E-01 |
| N-BUTANE | | 0.69281489E-01 | | 0.11990155E 00 |
| I-PENTANE | | 0.75739944E-01 | | 0.81837005E-01 |
| N-PENTANE | | 0.90854126E-01 | | 0.90445974E-01 |
| HEXANE | | 0.17685982E 00 | | 0.10325234E 00 |
| HEPTANE | | 0.18923932E 00 | | 0.66574464E-01 |
| OCTANE | | 0.10229647E 00 | | 0.21200277E-01 |
| NONANE | | 0.58918908E-01 | | 0.73107296E-02 |
| DECANE | | 0.12292193E 00 | | 0.93598904E-02 |

THIELE GEDDES CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 280.000 PSIA

DISTILLATE TEMP= 113.705 NO OF THEORETICAL PLATES= 15

REFLUX RATIO= 3.34050 DISTILLATE RATE= 0.17600 FEED PLATE NO= 4

| STAGE | VAPOUR | LIQUID | TEMPERATURE |
|-------|---------|---------|-------------|
| 1 | 0.76393 | 0.57972 | 174.317 |
| 2 | 0.75572 | 0.52180 | 210.928 |
| 3 | 0.69780 | 0.40331 | 250.350 |
| 4 | 0.40287 | 1.28132 | 311.129 |
| 5 | 0.45732 | 1.34086 | 318.815 |
| 6 | 0.51686 | 1.37964 | 323.797 |
| 7 | 0.55564 | 1.40616 | 327.286 |
| 8 | 0.58216 | 1.42549 | 329.987 |
| 9 | 0.60149 | 1.44050 | 332.369 |
| 10 | 0.61650 | 1.45356 | 334.885 |
| 11 | 0.62956 | 1.46581 | 338.065 |
| 12 | 0.64181 | 1.47854 | 342.846 |
| 13 | 0.65454 | 1.48887 | 351.038 |
| 14 | 0.66487 | 1.48208 | 366.868 |
| 15 | 0.65808 | 0.82400 | 401.473 |

CONDENSER HEAT LOAD= 0.46606247E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.80245114E 04 BTU/LB MOLE FEED

University of Alberta

Faculty of Science

Department of Chemistry

Chemistry 101: General Chemistry I

Final Examination - December 12, 2006

| Question | Answer | Mark | Total |
|----------------|-----------------|------|-------|
| 1. (10 marks) | 1.1 (10 marks) | 10 | 10 |
| 2. (10 marks) | 2.1 (10 marks) | 10 | 20 |
| 3. (10 marks) | 3.1 (10 marks) | 10 | 30 |
| 4. (10 marks) | 4.1 (10 marks) | 10 | 40 |
| 5. (10 marks) | 5.1 (10 marks) | 10 | 50 |
| 6. (10 marks) | 6.1 (10 marks) | 10 | 60 |
| 7. (10 marks) | 7.1 (10 marks) | 10 | 70 |
| 8. (10 marks) | 8.1 (10 marks) | 10 | 80 |
| 9. (10 marks) | 9.1 (10 marks) | 10 | 90 |
| 10. (10 marks) | 10.1 (10 marks) | 10 | 100 |
| 11. (10 marks) | 11.1 (10 marks) | 10 | 110 |
| 12. (10 marks) | 12.1 (10 marks) | 10 | 120 |
| 13. (10 marks) | 13.1 (10 marks) | 10 | 130 |
| 14. (10 marks) | 14.1 (10 marks) | 10 | 140 |
| 15. (10 marks) | 15.1 (10 marks) | 10 | 150 |
| 16. (10 marks) | 16.1 (10 marks) | 10 | 160 |
| 17. (10 marks) | 17.1 (10 marks) | 10 | 170 |
| 18. (10 marks) | 18.1 (10 marks) | 10 | 180 |
| 19. (10 marks) | 19.1 (10 marks) | 10 | 190 |
| 20. (10 marks) | 20.1 (10 marks) | 10 | 200 |

Total Score: 200/200

Signature: _____

COMPOSITIONS IN MOLE FRACTIONS

| COMPONENT | FEED | DISTILLATE | BOTTOMS |
|-----------|----------------|----------------|----------------|
| H2S | 0.56797020E-01 | 0.32266513E 00 | 0.80180136E-05 |
| CO2 | 0.65176909E-02 | 0.37031450E-01 | 0.10435193E-08 |
| METHANE | 0.26070760E-01 | 0.14812580E 00 | 0.11267345E-09 |
| ETHANE | 0.14432030E-01 | 0.81998107E-01 | 0.24324801E-07 |
| PROPANE | 0.44692740E-01 | 0.24960140E 00 | 0.92457953E-03 |
| I-BUTANE | 0.33519550E-01 | 0.71476532E-01 | 0.25411998E-01 |
| N-BUTANE | 0.76212289E-01 | 0.81281173E-01 | 0.77556777E-01 |
| I-PENTANE | 0.76815639E-01 | 0.48675204E-02 | 0.92183638E-01 |
| N-PENTANE | 0.90782119E-01 | 0.27987500E-02 | 0.10957522E 00 |
| HEXANE | 0.16387340E 00 | 0.14801209E-03 | 0.19884487E 00 |
| HEPTANE | 0.16759780E 00 | 0.60643534E-05 | 0.20339512E 00 |
| OCTANE | 0.87988829E-01 | 0.99945385E-07 | 0.10678308E 00 |
| NONANE | 0.49813780E-01 | 0.24355559E-08 | 0.60453920E-01 |
| DECANE | 0.10288640E 00 | 0.25368813E-09 | 0.12486276E 00 |

Table 1: Summary of results

| Method | Accuracy | Time | Memory |
|----------|----------|------|--------|
| Baseline | 0.75 | 1.0 | 1.0 |
| Method A | 0.80 | 1.2 | 1.1 |
| Method B | 0.85 | 1.5 | 1.2 |
| Method C | 0.90 | 1.8 | 1.3 |
| Method D | 0.95 | 2.0 | 1.4 |
| Method E | 0.98 | 2.2 | 1.5 |
| Method F | 0.99 | 2.5 | 1.6 |
| Method G | 0.99 | 2.8 | 1.7 |
| Method H | 0.99 | 3.0 | 1.8 |
| Method I | 0.99 | 3.2 | 1.9 |
| Method J | 0.99 | 3.5 | 2.0 |
| Method K | 0.99 | 3.8 | 2.1 |
| Method L | 0.99 | 4.0 | 2.2 |
| Method M | 0.99 | 4.2 | 2.3 |
| Method N | 0.99 | 4.5 | 2.4 |
| Method O | 0.99 | 4.8 | 2.5 |
| Method P | 0.99 | 5.0 | 2.6 |
| Method Q | 0.99 | 5.2 | 2.7 |
| Method R | 0.99 | 5.5 | 2.8 |
| Method S | 0.99 | 5.8 | 2.9 |
| Method T | 0.99 | 6.0 | 3.0 |
| Method U | 0.99 | 6.2 | 3.1 |
| Method V | 0.99 | 6.5 | 3.2 |
| Method W | 0.99 | 6.8 | 3.3 |
| Method X | 0.99 | 7.0 | 3.4 |
| Method Y | 0.99 | 7.2 | 3.5 |
| Method Z | 0.99 | 7.5 | 3.6 |

| COMPONENT | STAGE NUMBER 1
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.65503278E-01 | 0.19625140E 00 |
| CO2 | 0.25975847E-02 | 0.15252861E-01 |
| METHANE | 0.49258394E-02 | 0.47031630E-01 |
| ETHANE | 0.14299785E-01 | 0.46426468E-01 |
| PROPANE | 0.20889680E 00 | 0.28564984E 00 |
| I-BUTANE | 0.19956908E 00 | 0.14969980E 00 |
| N-BUTANE | 0.35269121E 00 | 0.21532882E 00 |
| I-PENTANE | 0.72092292E-01 | 0.24544248E-01 |
| N-PENTANE | 0.60124027E-01 | 0.17363701E-01 |
| HEXANE | 0.16127719E-01 | 0.22157508E-02 |
| HEPTANE | 0.28957758E-02 | 0.20204408E-03 |
| OCTANE | 0.24152049E-03 | 0.80369459E-05 |
| NONANE | 0.24922713E-04 | 0.42755825E-06 |
| DECANE | 0.10212261E-04 | 0.93267095E-07 |

| COMPONENT | STAGE NUMBER 2
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.35842540E-01 | 0.12538649E 00 |
| CO2 | 0.15997563E-02 | 0.10616190E-01 |
| METHANE | 0.38333574E-02 | 0.38270747E-01 |
| ETHANE | 0.76665835E-02 | 0.30065100E-01 |
| PROPANE | 0.12585282E 00 | 0.21835136E 00 |
| I-BUTANE | 0.17031261E 00 | 0.16971589E 00 |
| N-BUTANE | 0.34719648E 00 | 0.28945297E 00 |
| I-PENTANE | 0.11628684E 00 | 0.56431617E-01 |
| N-PENTANE | 0.11070470E 00 | 0.46771208E-01 |
| HEXANE | 0.57442160E-01 | 0.12406481E-01 |
| HEPTANE | 0.19113834E-01 | 0.22229598E-02 |
| OCTANE | 0.31209065E-02 | 0.18532281E-03 |
| NONANE | 0.59283760E-03 | 0.19122711E-04 |
| DECANE | 0.43461480E-03 | 0.78358120E-05 |

| COMPONENT | STAGE NUMBER 3
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.27294200E-01 | 0.10817096E 00 |
| CO2 | 0.14398257E-02 | 0.10534236E-01 |
| METHANE | 0.37805600E-02 | 0.40216065E-01 |
| ETHANE | 0.54886410E-02 | 0.26411778E-01 |
| PROPANE | 0.71848223E-01 | 0.15705172E 00 |
| I-BUTANE | 0.11210520E 00 | 0.14537795E 00 |
| N-BUTANE | 0.25178783E 00 | 0.28012305E 00 |
| I-PENTANE | 0.13209565E 00 | 0.88187564E-01 |
| N-PENTANE | 0.14029284E 00 | 0.83493588E-01 |
| HEXANE | 0.13342890E 00 | 0.42997472E-01 |
| HEPTANE | 0.78654501E-01 | 0.14297446E-01 |
| OCTANE | 0.23739605E-01 | 0.23344401E-02 |
| NONANE | 0.79757779E-02 | 0.44346678E-03 |
| DECANE | 0.10068261E-01 | 0.32512767E-03 |

| COMPONENT | STAGE NUMBER 4
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.21223104E-01 | 0.97136598E-01 |
| CO2 | 0.88776335E-03 | 0.71721487E-02 |
| METHANE | 0.19224457E-02 | 0.21786634E-01 |
| ETHANE | 0.31234956E-02 | 0.19873852E-01 |
| PROPANE | 0.46413778E-01 | 0.13620083E 00 |
| I-BUTANE | 0.65447025E-01 | 0.11899738E 00 |
| N-BUTANE | 0.14574474E 00 | 0.23508818E 00 |
| I-PENTANE | 0.97127070E-01 | 0.98531069E-01 |
| N-PENTANE | 0.10954988E 00 | 0.10206229E 00 |
| HEXANE | 0.16136574E 00 | 0.88418897E-01 |
| HEPTANE | 0.14962009E 00 | 0.49584478E-01 |
| OCTANE | 0.74211951E-01 | 0.14479904E-01 |
| NONANE | 0.40726659E-01 | 0.47823560E-02 |
| DECANE | 0.82636264E-01 | 0.59795482E-02 |

| COMPONENT | STAGE NUMBER 5 | |
|-----------|----------------|----------------|
| | LIQUID COMP. | VAPOUR COMP. |
| H2S | 0.12883362E-01 | 0.59455021E-01 |
| CO2 | 0.30931122E-03 | 0.24876192E-02 |
| METHANE | 0.48567316E-03 | 0.53869509E-02 |
| ETHANE | 0.13584561E-02 | 0.87524087E-02 |
| PROPANE | 0.42935387E-01 | 0.12839139E 00 |
| I-BUTANE | 0.73449619E-01 | 0.13759773E 00 |
| N-BUTANE | 0.16084609E 00 | 0.26863565E 00 |
| I-PENTANE | 0.99650552E-01 | 0.10604444E 00 |
| N-PENTANE | 0.11163305E 00 | 0.10951454E 00 |
| HEXANE | 0.15979601E 00 | 0.93842311E-01 |
| HEPTANE | 0.14612663E 00 | 0.52729861E-01 |
| OCTANE | 0.71872440E-01 | 0.15524762E-01 |
| NONANE | 0.39249912E-01 | 0.51813645E-02 |
| DECANE | 0.79403536E-01 | 0.65506208E-02 |

| COMPONENT | STAGE NUMBER 6 | |
|-----------|----------------|----------------|
| | LIQUID COMP. | VAPOUR COMP. |
| H2S | 0.72061117E-02 | 0.33411397E-01 |
| CO2 | 0.10004646E-03 | 0.80247100E-03 |
| METHANE | 0.11514525E-03 | 0.12600317E-02 |
| ETHANE | 0.54258455E-03 | 0.35243528E-02 |
| PROPANE | 0.36334103E-01 | 0.10991799E 00 |
| I-BUTANE | 0.78640639E-01 | 0.15004308E 00 |
| N-BUTANE | 0.17210112E 00 | 0.29364878E 00 |
| I-PENTANE | 0.10179552E 00 | 0.11156198E 00 |
| N-PENTANE | 0.11347907E 00 | 0.11492135E 00 |
| HEXANE | 0.15916030E 00 | 0.97549207E-01 |
| HEPTANE | 0.14417139E 00 | 0.54830583E-01 |
| OCTANE | 0.70506295E-01 | 0.16217634E-01 |
| NONANE | 0.38374572E-01 | 0.54460274E-02 |
| DECANE | 0.77473127E-01 | 0.69311545E-02 |

| Author | Title | Year |
|--------------|-------|------|
| 1. J. R. ... | ... | ... |
| 2. ... | ... | ... |
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| 11. ... | ... | ... |
| 12. ... | ... | ... |
| 13. ... | ... | ... |
| 14. ... | ... | ... |
| 15. ... | ... | ... |

| Author | Title | Year |
|---------|-------|------|
| 1. ... | ... | ... |
| 2. ... | ... | ... |
| 3. ... | ... | ... |
| 4. ... | ... | ... |
| 5. ... | ... | ... |
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| 10. ... | ... | ... |
| 11. ... | ... | ... |
| 12. ... | ... | ... |
| 13. ... | ... | ... |
| 14. ... | ... | ... |
| 15. ... | ... | ... |

| COMPONENT | STAGE NUMBER 7
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.38450624E-02 | 0.17881811E-01 |
| CO2 | 0.31018108E-04 | 0.24843423E-03 |
| METHANE | 0.26359472E-04 | 0.28594301E-03 |
| ETHANE | 0.20615222E-03 | 0.13472239E-02 |
| PROPANE | 0.29131918E-01 | 0.88848301E-01 |
| I-BUTANE | 0.81564328E-01 | 0.15758003E 00 |
| N-BUTANE | 0.18038391E 00 | 0.31230964E 00 |
| I-PENTANE | 0.10380404E 00 | 0.11605021E 00 |
| N-PENTANE | 0.11526635E 00 | 0.11926821E 00 |
| HEXANE | 0.15902352E 00 | 0.10030998E 00 |
| HEPTANE | 0.14302176E 00 | 0.56347281E-01 |
| OCTANE | 0.69651026E-01 | 0.16711457E-01 |
| NONANE | 0.37815565E-01 | 0.56334850E-02 |
| DECANE | 0.76228991E-01 | 0.72004294E-02 |

| COMPONENT | STAGE NUMBER 8
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.19898616E-02 | 0.92759174E-02 |
| CO2 | 0.93596964E-05 | 0.74921441E-04 |
| METHANE | 0.59044398E-05 | 0.63674628E-04 |
| ETHANE | 0.75778915E-04 | 0.49787124E-03 |
| PROPANE | 0.22492434E-01 | 0.69052483E-01 |
| I-BUTANE | 0.82544296E-01 | 0.16103199E 00 |
| N-BUTANE | 0.18611910E 00 | 0.32590173E 00 |
| I-PENTANE | 0.10594637E 00 | 0.12024937E 00 |
| N-PENTANE | 0.11725342E 00 | 0.12331982E 00 |
| HEXANE | 0.15928739E 00 | 0.10267184E 00 |
| HEPTANE | 0.14236981E 00 | 0.57589281E-01 |
| OCTANE | 0.69094162E-01 | 0.17107663E-01 |
| NONANE | 0.37437731E-01 | 0.57819057E-02 |
| DECANE | 0.75374387E-01 | 0.74122049E-02 |

| COMPONENT | STAGE NUMBER 9
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| H2S | 0.10069921E-02 | 0.47045117E-02 |
| CO2 | 0.27705894E-05 | 0.22179504E-04 |
| METHANE | 0.13031307E-05 | 0.13993341E-04 |
| ETHANE | 0.27178423E-04 | 0.17953225E-03 |
| PROPANE | 0.16843084E-01 | 0.52032270E-01 |
| I-BUTANE | 0.81702007E-01 | 0.16079184E 00 |
| N-BUTANE | 0.18927685E 00 | 0.33479929E 00 |
| I-PENTANE | 0.10850836E 00 | 0.12479537E 00 |
| N-PENTANE | 0.11976548E 00 | 0.12776842E 00 |
| HEXANE | 0.16006817E 00 | 0.10511418E 00 |
| HEPTANE | 0.14212057E 00 | 0.58799435E-01 |
| OCTANE | 0.68740999E-01 | 0.17482570E-01 |
| NONANE | 0.37175591E-01 | 0.59196571E-02 |
| DECANE | 0.74760665E-01 | 0.76064743E-02 |

| COMPONENT | STAGE NUMBER 10
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.50001608E-03 | 0.23420499E-02 |
| CO2 | 0.80774971E-06 | 0.64720003E-05 |
| METHANE | 0.28448169E-06 | 0.30447415E-05 |
| ETHANE | 0.95445284E-05 | 0.63463742E-04 |
| PROPANE | 0.12251153E-01 | 0.38114954E-01 |
| I-BUTANE | 0.78987711E-01 | 0.15692060E 00 |
| N-BUTANE | 0.18935114E 00 | 0.33856051E 00 |
| I-PENTANE | 0.11177100E 00 | 0.13032219E 00 |
| N-PENTANE | 0.12319593E 00 | 0.13338137E 00 |
| HEXANE | 0.16175054E 00 | 0.10825542E 00 |
| HEPTANE | 0.14234314E 00 | 0.60248732E-01 |
| OCTANE | 0.68556071E-01 | 0.17911991E-01 |
| NONANE | 0.36991464E-01 | 0.60732481E-02 |
| DECANE | 0.74291218E-01 | 0.78195591E-02 |

| COMPONENT | STAGE NUMBER 11
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.24339492E-03 | 0.11439964E-02 |
| CO2 | 0.23216031E-06 | 0.18636713E-05 |
| METHANE | 0.61551169E-07 | 0.65673190E-06 |
| ETHANE | 0.32792231E-05 | 0.22004361E-04 |
| PROPANE | 0.86210086E-02 | 0.27075395E-01 |
| I-BUTANE | 0.74148463E-01 | 0.14910655E 00 |
| N-BUTANE | 0.18515406E 00 | 0.33566167E 00 |
| I-PENTANE | 0.11583360E 00 | 0.13740594E 00 |
| N-PENTANE | 0.12786422E 00 | 0.14102127E 00 |
| HEXANE | 0.16521302E 00 | 0.11320484E 00 |
| HEPTANE | 0.14345732E 00 | 0.62445693E-01 |
| OCTANE | 0.68616768E-01 | 0.18529877E-01 |
| NONANE | 0.36894025E-01 | 0.62874178E-02 |
| DECANE | 0.73950555E-01 | 0.81115255E-02 |

| COMPONENT | STAGE NUMBER 12
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.11546338E-03 | 0.54565762E-03 |
| CO2 | 0.65630023E-07 | 0.52895624E-06 |
| METHANE | 0.13206506E-07 | 0.14045413E-06 |
| ETHANE | 0.10953160E-05 | 0.74587529E-05 |
| PROPANE | 0.58062741E-02 | 0.18503858E-01 |
| I-BUTANE | 0.66763011E-01 | 0.13673028E 00 |
| N-BUTANE | 0.17467198E 00 | 0.32331740E 00 |
| I-PENTANE | 0.12016253E 00 | 0.14620697E 00 |
| N-PENTANE | 0.13354591E 00 | 0.15135475E 00 |
| HEXANE | 0.17211118E 00 | 0.12204422E 00 |
| HEPTANE | 0.14672597E 00 | 0.66513891E-01 |
| OCTANE | 0.69272212E-01 | 0.19620848E-01 |
| NONANE | 0.36977063E-01 | 0.66489632E-02 |
| DECANE | 0.73827231E-01 | 0.85919485E-02 |

| COMPONENT | STAGE NUMBER 13
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.52574789E-04 | 0.25075231E-03 |
| CO2 | 0.18076029E-07 | 0.14695387E-06 |
| METHANE | 0.28031614E-08 | 0.29694486E-07 |
| ETHANE | 0.34959549E-06 | 0.24437887E-05 |
| PROPANE | 0.36577213E-02 | 0.11952862E-01 |
| I-BUTANE | 0.56266314E-01 | 0.11882813E 00 |
| N-BUTANE | 0.15499236E 00 | 0.29699337E 00 |
| I-PENTANE | 0.12243501E 00 | 0.15539001E 00 |
| N-PENTANE | 0.13807954E 00 | 0.16372627E 00 |
| HEXANE | 0.18452536E 00 | 0.13845146E 00 |
| HEPTANE | 0.15555663E 00 | 0.75376950E-01 |
| OCTANE | 0.71073616E-01 | 0.22044796E-01 |
| NONANE | 0.37791744E-01 | 0.74191396E-02 |
| DECANE | 0.74668765E-01 | 0.95726016E-02 |

| COMPONENT | STAGE NUMBER 14
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.22232415E-04 | 0.10780275E-03 |
| CO2 | 0.47164389E-08 | 0.39187444E-07 |
| METHANE | 0.58277717E-09 | 0.61382779E-08 |
| ETHANE | 0.10227298E-06 | 0.75273973E-06 |
| PROPANE | 0.20566516E-02 | 0.70453301E-02 |
| I-BUTANE | 0.42281118E-01 | 0.94508717E-01 |
| N-BUTANE | 0.12283577E 00 | 0.25096805E 00 |
| I-PENTANE | 0.11661026E 00 | 0.15992889E 00 |
| N-PENTANE | 0.13461193E 00 | 0.17340737E 00 |
| HEXANE | 0.20047616E 00 | 0.16677716E 00 |
| HEPTANE | 0.17590687E 00 | 0.96267240E-01 |
| OCTANE | 0.81602562E-01 | 0.28832771E-01 |
| NONANE | 0.42118216E-01 | 0.97059256E-02 |
| DECANE | 0.81478108E-01 | 0.12462631E-01 |

| COMPONENT | STAGE NUMBER 15
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| H2S | 0.80180136E-05 | 0.40030788E-04 |
| CO2 | 0.10435193E-08 | 0.93150706E-08 |
| METHANE | 0.11267345E-09 | 0.11714393E-08 |
| ETHANE | 0.24324801E-07 | 0.19986694E-06 |
| PROPANE | 0.92457953E-03 | 0.34741222E-02 |
| I-BUTANE | 0.25411998E-01 | 0.63403156E-01 |
| N-BUTANE | 0.77556776E-01 | 0.17952925E 00 |
| I-PENTANE | 0.92183636E-01 | 0.14719459E 00 |
| N-PENTANE | 0.10957522E 00 | 0.16595981E 00 |
| HEXANE | 0.19884487E 00 | 0.20251864E 00 |
| HEPTANE | 0.20339512E 00 | 0.14149096E 00 |
| OCTANE | 0.10678308E 00 | 0.50076382E-01 |
| NONANE | 0.60453920E-01 | 0.19162126E-01 |
| DECANE | 0.12486276E 00 | 0.27161652E-01 |

| Author | Title | Year |
|--------------|-------|------|
| Adams, J. W. | ... | 1978 |
| Adams, J. W. | ... | 1979 |
| Adams, J. W. | ... | 1980 |
| Adams, J. W. | ... | 1981 |
| Adams, J. W. | ... | 1982 |
| Adams, J. W. | ... | 1983 |
| Adams, J. W. | ... | 1984 |
| Adams, J. W. | ... | 1985 |
| Adams, J. W. | ... | 1986 |
| Adams, J. W. | ... | 1987 |
| Adams, J. W. | ... | 1988 |
| Adams, J. W. | ... | 1989 |
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| Adams, J. W. | ... | 1991 |
| Adams, J. W. | ... | 1992 |
| Adams, J. W. | ... | 1993 |
| Adams, J. W. | ... | 1994 |
| Adams, J. W. | ... | 1995 |
| Adams, J. W. | ... | 1996 |
| Adams, J. W. | ... | 1997 |
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| Adams, J. W. | ... | 2003 |
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| Adams, J. W. | ... | 2010 |
| Adams, J. W. | ... | 2011 |
| Adams, J. W. | ... | 2012 |
| Adams, J. W. | ... | 2013 |
| Adams, J. W. | ... | 2014 |
| Adams, J. W. | ... | 2015 |
| Adams, J. W. | ... | 2016 |
| Adams, J. W. | ... | 2017 |
| Adams, J. W. | ... | 2018 |
| Adams, J. W. | ... | 2019 |
| Adams, J. W. | ... | 2020 |
| Adams, J. W. | ... | 2021 |
| Adams, J. W. | ... | 2022 |
| Adams, J. W. | ... | 2023 |
| Adams, J. W. | ... | 2024 |
| Adams, J. W. | ... | 2025 |

SHORT CUT DESIGN PROGRAM
INCLUDING (MODIFIED BERGAMINI'S) RIGOROUS
CALCULATIONAL PROCEDURE CHECK

SAMPLE COMPUTER OUTPUT
PROBLEM 6

OBJECT PROGRAM IS BEING ENTERED INTO STORAGE.

FEED CONDITION

FLASH TEMP= 305.130 F FRACTION LIQUID= 0.64258000E 00

| COMPONENT | MF | FLASH LIQUID | MF | FLASH VAPOUR |
|-----------|----|----------------|----|----------------|
| NITROGEN | | 0.75538016E-04 | | 0.20621079E-02 |
| H2S | | 0.39793104E-01 | | 0.18341275E 00 |
| CO2 | | 0.39669332E-02 | | 0.33529188E-01 |
| METHANE | | 0.14135402E-01 | | 0.17569504E 00 |
| ETHANE | | 0.83331625E-02 | | 0.55350852E-01 |
| PROPANE | | 0.31033582E-01 | | 0.92562757E-01 |
| I-BUTANE | | 0.25989316E-01 | | 0.46684071E-01 |
| N-BUTANE | | 0.62108804E-01 | | 0.98232735E-01 |
| I-PENTANE | | 0.70069022E-01 | | 0.67436211E-01 |
| N-PENTANE | | 0.83734698E-01 | | 0.73636853E-01 |
| HEXANE | | 0.17091161E 00 | | 0.85037760E-01 |
| HEPTANE | | 0.19049665E 00 | | 0.55319548E-01 |
| OCTANE | | 0.10635331E 00 | | 0.17584170E-01 |
| NONANE | | 0.62086809E-01 | | 0.59595653E-02 |
| DECANE | | 0.13091207E 00 | | 0.74964221E-02 |

SHORT CUT METHOD

BASIS ONE LB-MOLE FEED

SHORTCUT MINIMUM REFLUX= 2.2332

SHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL REFLUX= 7.8895

SHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATING REFLUX= 14.4444

DISTILLATE TEMP= 135.382 NO OF THEORETICAL PLATES= 15

BOTTOMS TEMP= 426.636 F COLUMN PRESSURE= 280.000 PSIA

REFLUX RATIO= 3.29928 DISTILLATE RATE= 0.35543 FEED PLATE NO= 8

CONDENSER HEAT LOAD= 0.98611901E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.13668382E 05 BTU/LB MOLE FEED

COMPOSITIONS IN MOLE FRACTIONS

| COMPONENT | FEED | DISTILLATE | BOTTOMS |
|-----------|----------------|----------------|----------------|
| NITROGEN | 0.78554594E-03 | 0.22101032E-02 | 0.15728879E-13 |
| H2S | 0.91123329E-01 | 0.25636472E 00 | 0.40003616E-05 |
| CO2 | 0.14532600E-01 | 0.40886903E-01 | 0.36244153E-08 |
| METHANE | 0.71877454E-01 | 0.20222444E 00 | 0.10464971E-08 |
| ETHANE | 0.25137470E-01 | 0.70723165E-01 | 0.76004779E-07 |
| PROPANE | 0.53024352E-01 | 0.14894263E 00 | 0.13197852E-03 |
| I-BUTANE | 0.33385703E-01 | 0.85201108E-01 | 0.48130490E-02 |
| N-BUTANE | 0.75019637E-01 | 0.17680826E 00 | 0.18890173E-01 |
| I-PENTANE | 0.69128043E-01 | 0.11050516E-01 | 0.10115383E 00 |
| N-PENTANE | 0.80125686E-01 | 0.54972451E-02 | 0.12127817E 00 |
| HEXANE | 0.14021995E 00 | 0.89782863E-04 | 0.21749215E 00 |
| HEPTANE | 0.14218381E 00 | 0.11641031E-05 | 0.22058782E 00 |
| OCTANE | 0.74626864E-01 | 0.59132812E-08 | 0.11577847E 00 |
| NONANE | 0.42026708E-01 | 0.43170936E-10 | 0.65201563E-01 |
| DECANE | 0.86802826E-01 | 0.14235957E-11 | 0.13466865E 00 |

Section 1: Introduction

1.1 Background and Motivation

The purpose of this section is to provide a brief overview of the research area and the motivation for the study.

The research is motivated by the need to understand the underlying mechanisms of the observed phenomena.

The study aims to investigate the relationship between the variables and the factors influencing the outcome.

The research is organized into several sections, each focusing on a specific aspect of the problem.

The first section discusses the theoretical background and the existing literature.

The second section describes the methodology used in the study, including the data collection and analysis techniques.

The third section presents the results of the study, which are discussed in detail in the following sections.

The final section concludes the study and provides recommendations for future research.

Section 2: Literature Review

2.1 Introduction

2.2 Theoretical Framework

2.3 Empirical Studies

2.4 Summary

| | | | |
|----------------------|-----------------------|---------------------------|-----------------------|
| 1. Introduction | 2.1 Introduction | 2.2 Theoretical Framework | 2.3 Empirical Studies |
| 2. Literature Review | 2.1.1 Background | 2.2.1 Conceptual Model | 2.3.1 Data Collection |
| 3. Methodology | 2.1.2 Research Design | 2.2.2 Hypotheses | 2.3.2 Data Analysis |
| 4. Results | 2.1.3 Data Collection | 2.2.3 Results | 2.3.3 Discussion |
| 5. Discussion | 2.1.4 Data Analysis | 2.2.4 Conclusions | 2.3.4 Future Research |
| 6. Conclusion | 2.1.5 Summary | 2.2.5 References | 2.3.5 Appendix |
| | 2.1.6 References | 2.2.6 Appendix | 2.3.6 Bibliography |
| | 2.1.7 Appendix | 2.2.7 Bibliography | 2.3.7 Index |
| | 2.1.8 Index | 2.2.8 Index | 2.3.8 Index |
| | 2.1.9 Index | 2.2.9 Index | 2.3.9 Index |
| | 2.1.10 Index | 2.2.10 Index | 2.3.10 Index |
| | 2.1.11 Index | 2.2.11 Index | 2.3.11 Index |
| | 2.1.12 Index | 2.2.12 Index | 2.3.12 Index |
| | 2.1.13 Index | 2.2.13 Index | 2.3.13 Index |
| | 2.1.14 Index | 2.2.14 Index | 2.3.14 Index |
| | 2.1.15 Index | 2.2.15 Index | 2.3.15 Index |
| | 2.1.16 Index | 2.2.16 Index | 2.3.16 Index |
| | 2.1.17 Index | 2.2.17 Index | 2.3.17 Index |
| | 2.1.18 Index | 2.2.18 Index | 2.3.18 Index |
| | 2.1.19 Index | 2.2.19 Index | 2.3.19 Index |
| | 2.1.20 Index | 2.2.20 Index | 2.3.20 Index |

BERGAMINI CALCULATION PROCEEDURE

BASIS ONE LB-MOLE FEED

COLUMN PRESSURE= 280.000 PSIA

DISTILLATE TEMP= 131.459 NO OF THEORETICAL PLATES= 15

REFLUX RATIO= 3.29928 DISTILLATE RATE= 0.35543 FEED PLATE NO= 8

| STAGE | VAPOUR | LIQUID | TEMPERATURE |
|-------|---------|---------|-------------|
| 1 | 1.52811 | 1.28770 | 187.740 |
| 2 | 1.64313 | 1.31543 | 206.022 |
| 3 | 1.67086 | 1.29709 | 215.406 |
| 4 | 1.65252 | 1.26222 | 223.469 |
| 5 | 1.61765 | 1.20442 | 232.885 |
| 6 | 1.55985 | 1.11155 | 245.637 |
| 7 | 1.46698 | 1.31711 | 265.998 |
| 8 | 1.31513 | 1.77443 | 318.427 |
| 9 | 1.12987 | 1.86035 | 331.450 |
| 10 | 1.21579 | 1.90269 | 340.685 |
| 11 | 1.25812 | 1.92654 | 349.363 |
| 12 | 1.28198 | 1.93317 | 359.168 |
| 13 | 1.28860 | 1.91329 | 372.183 |
| 14 | 1.26872 | 1.84508 | 392.351 |
| 15 | 1.20052 | 0.64457 | 427.841 |

CONDENSER HEAT LOAD= 0.95240413E 04 BTU/LB MOLE FEED

REBOILER HEAT LOAD= 0.13369079E 05 BTU/LB MOLE FEED

[illegible]

COMPOSITIONS IN MOLE FRACTIONS

| COMPONENT | FEED | DISTILLATE | BOTTOMS |
|-----------|----------------|----------------|----------------|
| NITROGEN | 0.78554594E-03 | 0.22100914E-02 | 0.77487824E-13 |
| H2S | 0.91123329E-01 | 0.25636618E 00 | 0.24355673E-05 |
| CO2 | 0.14532600E-01 | 0.40886685E-01 | 0.29562642E-08 |
| METHANE | 0.71877454E-01 | 0.20222335E 00 | 0.17210124E-08 |
| ETHANE | 0.25137470E-01 | 0.70722881E-01 | 0.22836665E-07 |
| PROPANE | 0.53024352E-01 | 0.14910239E 00 | 0.43443123E-04 |
| I-BUTANE | 0.33385703E-01 | 0.90550647E-01 | 0.18628813E-02 |
| N-BUTANE | 0.75019637E-01 | 0.18341116E 00 | 0.15248629E-01 |
| I-PENTANE | 0.69128043E-01 | 0.34607292E-02 | 0.10533938E 00 |
| N-PENTANE | 0.80125686E-01 | 0.10629355E-02 | 0.12372376E 00 |
| HEXANE | 0.14021995E 00 | 0.29849873E-05 | 0.21754068E 00 |
| HEPTANE | 0.14218381E 00 | 0.11530399E-07 | 0.22058913E 00 |
| OCTANE | 0.74626864E-01 | 0.16064304E-10 | 0.11577883E 00 |
| NONANE | 0.42026708E-01 | 0.42077769E-13 | 0.65201760E-01 |
| DECANE | 0.86802826E-01 | 0.52417237E-15 | 0.13466906E 00 |

| COMPONENT | STAGE NUMBER 1
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.21487325E-04 | 0.56640624E-03 |
| H2S | 0.44630979E-01 | 0.14376647E 00 |
| CO2 | 0.26036259E-02 | 0.16052595E-01 |
| METHANE | 0.66754676E-02 | 0.63908168E-01 |
| ETHANE | 0.10900548E-01 | 0.37594818E-01 |
| PROPANE | 0.10167713E 00 | 0.15148282E 00 |
| I-BUTANE | 0.19283296E 00 | 0.16144204E 00 |
| N-BUTANE | 0.58915475E 00 | 0.40584559E 00 |
| I-PENTANE | 0.35781210E-01 | 0.14076691E-01 |
| N-PENTANE | 0.15515567E-01 | 0.52304085E-02 |
| HEXANE | 0.20306793E-03 | 0.33740459E-04 |
| HEPTANE | 0.32157177E-05 | 0.27947593E-06 |
| OCTANE | 0.21104125E-07 | 0.90292361E-09 |
| NONANE | 0.22047829E-09 | 0.50002252E-11 |
| DECANE | 0.10243764E-10 | 0.12681611E-12 |

| COMPONENT | STAGE NUMBER 2
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.19970894E-04 | 0.49491645E-03 |
| H2S | 0.26052322E-01 | 0.90432599E-01 |
| CO2 | 0.16784356E-02 | 0.10884847E-01 |
| METHANE | 0.50892366E-02 | 0.48975520E-01 |
| ETHANE | 0.63652848E-02 | 0.23841050E-01 |
| PROPANE | 0.67198594E-01 | 0.11193595E 00 |
| I-BUTANE | 0.17735317E 00 | 0.17070770E 00 |
| N-BUTANE | 0.62412344E 00 | 0.50138609E 00 |
| I-PENTANE | 0.61069727E-01 | 0.28789787E-01 |
| N-PENTANE | 0.30267941E-01 | 0.12389237E-01 |
| HEXANE | 0.75947238E-03 | 0.15978688E-03 |
| HEPTANE | 0.22134297E-04 | 0.25226021E-05 |
| OCTANE | 0.28356536E-06 | 0.16542449E-07 |
| NONANE | 0.54110596E-08 | 0.17279450E-09 |
| DECANE | 0.44706115E-09 | 0.80279914E-11 |

| COMPONENT | STAGE NUMBER 3
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.19994702E-04 | 0.48586648E-03 |
| H2S | 0.20912458E-01 | 0.75046068E-01 |
| CO2 | 0.15083376E-02 | 0.10019050E-01 |
| METHANE | 0.48467865E-02 | 0.47024791E-01 |
| ETHANE | 0.51201534E-02 | 0.20055819E-01 |
| PROPANE | 0.48050837E-01 | 0.84621661E-01 |
| I-BUTANE | 0.15443178E 00 | 0.15888802E 00 |
| N-BUTANE | 0.61350100E 00 | 0.53037247E 00 |
| I-PENTANE | 0.95213876E-01 | 0.48814794E-01 |
| N-PENTANE | 0.53701725E-01 | 0.24055277E-01 |
| HEXANE | 0.25542959E-02 | 0.59854783E-03 |
| HEPTANE | 0.13532873E-03 | 0.17428209E-04 |
| OCTANE | 0.33298935E-05 | 0.22324705E-06 |
| NONANE | 0.11458647E-06 | 0.42599954E-08 |
| DECANE | 0.16632537E-07 | 0.35195972E-09 |

| COMPONENT | STAGE NUMBER 4
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.20396303E-04 | 0.49105559E-03 |
| H2S | 0.19439592E-01 | 0.71555446E-01 |
| CO2 | 0.14728375E-02 | 0.99781003E-02 |
| METHANE | 0.48235928E-02 | 0.47299881E-01 |
| ETHANE | 0.47155355E-02 | 0.19230434E-01 |
| PROPANE | 0.37807159E-01 | 0.69785691E-01 |
| I-BUTANE | 0.12952490E 00 | 0.14069179E 00 |
| N-BUTANE | 0.56771583E 00 | 0.52099434E 00 |
| I-PENTANE | 0.13775368E 00 | 0.75478984E-01 |
| N-PENTANE | 0.88070631E-01 | 0.42379818E-01 |
| HEXANE | 0.78675571E-02 | 0.20055426E-02 |
| HEPTANE | 0.75058038E-03 | 0.10622378E-03 |
| OCTANE | 0.35036156E-04 | 0.26136808E-05 |
| NONANE | 0.21552526E-05 | 0.89940442E-07 |
| DECANE | 0.54506098E-06 | 0.13055098E-07 |

| COMPONENT | STAGE NUMBER 5
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.20963492E-04 | 0.50152426E-03 |
| H2S | 0.18883944E-01 | 0.71497816E-01 |
| CO2 | 0.14624912E-02 | 0.10132967E-01 |
| METHANE | 0.48429988E-02 | 0.48196863E-01 |
| ETHANE | 0.44904243E-02 | 0.19218869E-01 |
| PROPANE | 0.31942534E-01 | 0.62261283E-01 |
| I-BUTANE | 0.10468871E 00 | 0.12096136E 00 |
| N-BUTANE | 0.49205898E 00 | 0.48327525E 00 |
| I-PENTANE | 0.18334600E 00 | 0.10824642E 00 |
| N-PENTANE | 0.13222633E 00 | 0.68953038E-01 |
| HEXANE | 0.21931474E-01 | 0.61395296E-02 |
| HEPTANE | 0.37284258E-02 | 0.58566313E-03 |
| OCTANE | 0.32574956E-03 | 0.27337909E-04 |
| NONANE | 0.35498662E-04 | 0.16816940E-05 |
| DECANE | 0.15505879E-04 | 0.42529854E-06 |

| COMPONENT | STAGE NUMBER 6
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.21864029E-04 | 0.51978941E-03 |
| H2S | 0.18601929E-01 | 0.72997865E-01 |
| CO2 | 0.14658434E-02 | 0.10445890E-01 |
| METHANE | 0.49042629E-02 | 0.49319100E-01 |
| ETHANE | 0.42865252E-02 | 0.19582492E-01 |
| PROPANE | 0.28003972E-01 | 0.58639178E-01 |
| I-BUTANE | 0.81015174E-01 | 0.10146713E 00 |
| N-BUTANE | 0.39302432E 00 | 0.42172890E 00 |
| I-PENTANE | 0.21884111E 00 | 0.14235642E 00 |
| N-PENTANE | 0.17680315E 00 | 0.10233876E 00 |
| HEXANE | 0.53585488E-01 | 0.16934735E-01 |
| HEPTANE | 0.16015009E-01 | 0.28788501E-02 |
| OCTANE | 0.25737780E-02 | 0.25152260E-03 |
| NONANE | 0.49117427E-03 | 0.27409754E-04 |
| DECANE | 0.36645190E-03 | 0.11972630E-04 |

| Author | Title | Year |
|-----------------|------------------------------|------|
| 1. Smith, J. | 1. The History of the World | 1800 |
| 2. Jones, A. | 2. The History of the World | 1801 |
| 3. Brown, C. | 3. The History of the World | 1802 |
| 4. White, D. | 4. The History of the World | 1803 |
| 5. Black, E. | 5. The History of the World | 1804 |
| 6. Green, F. | 6. The History of the World | 1805 |
| 7. Grey, G. | 7. The History of the World | 1806 |
| 8. Hall, H. | 8. The History of the World | 1807 |
| 9. Hart, I. | 9. The History of the World | 1808 |
| 10. Hill, J. | 10. The History of the World | 1809 |
| 11. Holmes, K. | 11. The History of the World | 1810 |
| 12. Howard, L. | 12. The History of the World | 1811 |
| 13. Hughes, M. | 13. The History of the World | 1812 |
| 14. Hudson, N. | 14. The History of the World | 1813 |
| 15. Hunt, O. | 15. The History of the World | 1814 |
| 16. Ingram, P. | 16. The History of the World | 1815 |
| 17. Jackson, Q. | 17. The History of the World | 1816 |
| 18. James, R. | 18. The History of the World | 1817 |
| 19. Johnson, S. | 19. The History of the World | 1818 |
| 20. Jones, T. | 20. The History of the World | 1819 |

| Author | Title | Year |
|-----------------|------------------------------|------|
| 21. King, U. | 21. The History of the World | 1820 |
| 22. Knight, V. | 22. The History of the World | 1821 |
| 23. Lamb, W. | 23. The History of the World | 1822 |
| 24. Lane, X. | 24. The History of the World | 1823 |
| 25. Lee, Y. | 25. The History of the World | 1824 |
| 26. Lewis, Z. | 26. The History of the World | 1825 |
| 27. Lloyd, A. | 27. The History of the World | 1826 |
| 28. Long, B. | 28. The History of the World | 1827 |
| 29. Love, C. | 29. The History of the World | 1828 |
| 30. Lucas, D. | 30. The History of the World | 1829 |
| 31. Lyons, E. | 31. The History of the World | 1830 |
| 32. Mack, F. | 32. The History of the World | 1831 |
| 33. Madson, G. | 33. The History of the World | 1832 |
| 34. Magee, H. | 34. The History of the World | 1833 |
| 35. Mahoney, I. | 35. The History of the World | 1834 |
| 36. Main, J. | 36. The History of the World | 1835 |
| 37. Mann, K. | 37. The History of the World | 1836 |
| 38. Marks, L. | 38. The History of the World | 1837 |
| 39. Martin, M. | 39. The History of the World | 1838 |
| 40. Mason, N. | 40. The History of the World | 1839 |

| COMPONENT | STAGE NUMBER 7
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.23325746E-04 | 0.55205087E-03 |
| H2S | 0.18416796E-01 | 0.76209964E-01 |
| CO2 | 0.14828494E-02 | 0.11017141E-01 |
| METHANE | 0.50119132E-02 | 0.52712817E-01 |
| ETHANE | 0.40192353E-02 | 0.20383428E-01 |
| PROPANE | 0.24516366E-01 | 0.57344975E-01 |
| I-BUTANE | 0.58824050E-01 | 0.83325529E-01 |
| N-BUTANE | 0.27870834E 00 | 0.34223703E 00 |
| I-PENTANE | 0.22118604E 00 | 0.16665647E 00 |
| N-PENTANE | 0.19802890E 00 | 0.13422295E 00 |
| HEXANE | 0.10703199E 00 | 0.40602953E-01 |
| HEPTANE | 0.55120018E-01 | 0.12134726E-01 |
| OCTANE | 0.15875811E-01 | 0.19501759E-02 |
| NONANE | 0.52162020E-02 | 0.37216738E-03 |
| DECANE | 0.65381628E-02 | 0.27766406E-03 |

| COMPONENT | STAGE NUMBER 8
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.28263355E-05 | 0.60311814E-04 |
| H2S | 0.82910864E-02 | 0.37903157E-01 |
| CO2 | 0.43524196E-03 | 0.34244913E-02 |
| METHANE | 0.11162539E-02 | 0.11932330E-01 |
| ETHANE | 0.12945879E-02 | 0.80997919E-02 |
| PROPANE | 0.13557472E-01 | 0.39719871E-01 |
| I-BUTANE | 0.38225476E-01 | 0.70728858E-01 |
| N-BUTANE | 0.18288284E 00 | 0.30204646E 00 |
| I-PENTANE | 0.19212985E 00 | 0.20409360E 00 |
| N-PENTANE | 0.18223688E 00 | 0.17856803E 00 |
| HEXANE | 0.14186204E 00 | 0.84051134E-01 |
| HEPTANE | 0.10925149E 00 | 0.40147470E-01 |
| OCTANE | 0.50124648E-01 | 0.11114205E-01 |
| NONANE | 0.26324284E-01 | 0.36022437E-02 |
| DECANE | 0.52265034E-01 | 0.45080744E-02 |

| Author | Title | Year |
|--------------|-------|------|
| Adams, J. W. | ... | 1971 |
| Adams, J. W. | ... | 1972 |
| Adams, J. W. | ... | 1973 |
| Adams, J. W. | ... | 1974 |
| Adams, J. W. | ... | 1975 |
| Adams, J. W. | ... | 1976 |
| Adams, J. W. | ... | 1977 |
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| Adams, J. W. | ... | 2014 |
| Adams, J. W. | ... | 2015 |
| Adams, J. W. | ... | 2016 |
| Adams, J. W. | ... | 2017 |
| Adams, J. W. | ... | 2018 |
| Adams, J. W. | ... | 2019 |
| Adams, J. W. | ... | 2020 |
| Adams, J. W. | ... | 2021 |
| Adams, J. W. | ... | 2022 |
| Adams, J. W. | ... | 2023 |
| Adams, J. W. | ... | 2024 |
| Adams, J. W. | ... | 2025 |

| Author | Title | Year |
|--------------|-------|------|
| Adams, J. W. | ... | 1971 |
| Adams, J. W. | ... | 1972 |
| Adams, J. W. | ... | 1973 |
| Adams, J. W. | ... | 1974 |
| Adams, J. W. | ... | 1975 |
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| Adams, J. W. | ... | 1989 |
| Adams, J. W. | ... | 1990 |
| Adams, J. W. | ... | 1991 |
| Adams, J. W. | ... | 1992 |
| Adams, J. W. | ... | 1993 |
| Adams, J. W. | ... | 1994 |
| Adams, J. W. | ... | 1995 |
| Adams, J. W. | ... | 1996 |
| Adams, J. W. | ... | 1997 |
| Adams, J. W. | ... | 1998 |
| Adams, J. W. | ... | 1999 |
| Adams, J. W. | ... | 2000 |
| Adams, J. W. | ... | 2001 |
| Adams, J. W. | ... | 2002 |
| Adams, J. W. | ... | 2003 |
| Adams, J. W. | ... | 2004 |
| Adams, J. W. | ... | 2005 |
| Adams, J. W. | ... | 2006 |
| Adams, J. W. | ... | 2007 |
| Adams, J. W. | ... | 2008 |
| Adams, J. W. | ... | 2009 |
| Adams, J. W. | ... | 2010 |
| Adams, J. W. | ... | 2011 |
| Adams, J. W. | ... | 2012 |
| Adams, J. W. | ... | 2013 |
| Adams, J. W. | ... | 2014 |
| Adams, J. W. | ... | 2015 |
| Adams, J. W. | ... | 2016 |
| Adams, J. W. | ... | 2017 |
| Adams, J. W. | ... | 2018 |
| Adams, J. W. | ... | 2019 |
| Adams, J. W. | ... | 2020 |
| Adams, J. W. | ... | 2021 |
| Adams, J. W. | ... | 2022 |
| Adams, J. W. | ... | 2023 |
| Adams, J. W. | ... | 2024 |
| Adams, J. W. | ... | 2025 |

| COMPONENT | STAGE NUMBER 9
LIQUID COMP. | VAPOUR COMP. |
|-----------|--------------------------------|----------------|
| NITROGEN | 0.22046920E-06 | 0.44389781E-05 |
| H2S | 0.28148080E-02 | 0.13020401E-01 |
| CO2 | 0.86910395E-04 | 0.68357940E-03 |
| METHANE | 0.16763812E-03 | 0.17531619E-02 |
| ETHANE | 0.31505024E-03 | 0.20332372E-02 |
| PROPANE | 0.70032369E-02 | 0.21268269E-01 |
| I-BUTANE | 0.30327432E-01 | 0.58973143E-01 |
| N-BUTANE | 0.15928225E 00 | 0.27853109E 00 |
| I-PENTANE | 0.21131841E 00 | 0.24165051E 00 |
| N-PENTANE | 0.20323752E 00 | 0.21562313E 00 |
| HEXANE | 0.15022185E 00 | 0.98681545E-01 |
| HEPTANE | 0.10987250E 00 | 0.45724779E-01 |
| OCTANE | 0.49278020E-01 | 0.12663874E-01 |
| NONANE | 0.25591204E-01 | 0.41416833E-02 |
| DECANE | 0.50482968E-01 | 0.52471815E-02 |

| COMPONENT | STAGE NUMBER 10
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITROGEN | 0.17325416E-07 | 0.33735987E-06 |
| H2S | 0.92325273E-03 | 0.43059016E-02 |
| CO2 | 0.16845763E-04 | 0.13298791E-03 |
| METHANE | 0.24792180E-04 | 0.25651737E-03 |
| ETHANE | 0.72842927E-04 | 0.48207481E-03 |
| PROPANE | 0.34298453E-02 | 0.10693254E-01 |
| I-BUTANE | 0.22570427E-01 | 0.45419071E-01 |
| N-BUTANE | 0.12958267E 00 | 0.23564753E 00 |
| I-PENTANE | 0.22270001E 00 | 0.26750750E 00 |
| N-PENTANE | 0.21937158E 00 | 0.24539497E 00 |
| HEXANE | 0.16294077E 00 | 0.11453003E 00 |
| HEPTANE | 0.11340983E 00 | 0.51171581E-01 |
| OCTANE | 0.49582278E-01 | 0.14019912E-01 |
| NONANE | 0.25456397E-01 | 0.45900572E-02 |
| DECANE | 0.49918466E-01 | 0.58482909E-02 |

| Year | Month | Day | Time | Location | Notes |
|------|-------|-----|-------|----------|---------------------|
| 1971 | Jan | 1 | 10:00 | Room 101 | First meeting |
| 1971 | Jan | 2 | 10:00 | Room 101 | Second meeting |
| 1971 | Jan | 3 | 10:00 | Room 101 | Third meeting |
| 1971 | Jan | 4 | 10:00 | Room 101 | Fourth meeting |
| 1971 | Jan | 5 | 10:00 | Room 101 | Fifth meeting |
| 1971 | Jan | 6 | 10:00 | Room 101 | Sixth meeting |
| 1971 | Jan | 7 | 10:00 | Room 101 | Seventh meeting |
| 1971 | Jan | 8 | 10:00 | Room 101 | Eighth meeting |
| 1971 | Jan | 9 | 10:00 | Room 101 | Ninth meeting |
| 1971 | Jan | 10 | 10:00 | Room 101 | Tenth meeting |
| 1971 | Jan | 11 | 10:00 | Room 101 | Eleventh meeting |
| 1971 | Jan | 12 | 10:00 | Room 101 | Twelfth meeting |
| 1971 | Jan | 13 | 10:00 | Room 101 | Thirteenth meeting |
| 1971 | Jan | 14 | 10:00 | Room 101 | Fourteenth meeting |
| 1971 | Jan | 15 | 10:00 | Room 101 | Fifteenth meeting |
| 1971 | Jan | 16 | 10:00 | Room 101 | Sixteenth meeting |
| 1971 | Jan | 17 | 10:00 | Room 101 | Seventeenth meeting |
| 1971 | Jan | 18 | 10:00 | Room 101 | Eighteenth meeting |
| 1971 | Jan | 19 | 10:00 | Room 101 | Nineteenth meeting |
| 1971 | Jan | 20 | 10:00 | Room 101 | Twentieth meeting |

| Year | Month | Day | Time | Location | Notes |
|------|-------|-----|-------|----------|------------------------|
| 1971 | Jan | 21 | 10:00 | Room 101 | Twenty-first meeting |
| 1971 | Jan | 22 | 10:00 | Room 101 | Twenty-second meeting |
| 1971 | Jan | 23 | 10:00 | Room 101 | Twenty-third meeting |
| 1971 | Jan | 24 | 10:00 | Room 101 | Twenty-fourth meeting |
| 1971 | Jan | 25 | 10:00 | Room 101 | Twenty-fifth meeting |
| 1971 | Jan | 26 | 10:00 | Room 101 | Twenty-sixth meeting |
| 1971 | Jan | 27 | 10:00 | Room 101 | Twenty-seventh meeting |
| 1971 | Jan | 28 | 10:00 | Room 101 | Twenty-eighth meeting |
| 1971 | Jan | 29 | 10:00 | Room 101 | Twenty-ninth meeting |
| 1971 | Jan | 30 | 10:00 | Room 101 | Thirtieth meeting |
| 1971 | Jan | 31 | 10:00 | Room 101 | Final meeting |

| COMPONENT | STAGE NUMBER 11
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITROGEN | 0.13817994E-08 | 0.26200788E-07 |
| H2S | 0.29677713E-03 | 0.13949662E-02 |
| CO2 | 0.32057851E-05 | 0.25473944E-04 |
| METHANE | 0.36489367E-05 | 0.37491762E-04 |
| ETHANE | 0.16222231E-04 | 0.11014698E-03 |
| PROPANE | 0.16154872E-02 | 0.51646212E-02 |
| I-BUTANE | 0.15976040E-01 | 0.33178425E-01 |
| N-BUTANE | 0.99819166E-01 | 0.18815337E 00 |
| I-PENTANE | 0.22526080E 00 | 0.28282115E 00 |
| N-PENTANE | 0.22877754E 00 | 0.26836975E 00 |
| HEXANE | 0.18083364E 00 | 0.13497050E 00 |
| HEPTANE | 0.12074038E 00 | 0.58504335E-01 |
| OCTANE | 0.50955392E-01 | 0.15671307E-01 |
| NONANE | 0.25708634E-01 | 0.50957604E-02 |
| DECANE | 0.49993072E-01 | 0.65026858E-02 |

| COMPONENT | STAGE NUMBER 12
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITROGEN | 0.11243005E-09 | 0.20764423E-08 |
| H2S | 0.93797812E-04 | 0.44475356E-03 |
| CO2 | 0.59972617E-06 | 0.48159661E-05 |
| METHANE | 0.53663290E-06 | 0.54825274E-05 |
| ETHANE | 0.34813751E-05 | 0.24366268E-04 |
| PROPANE | 0.73148589E-03 | 0.24058122E-02 |
| I-BUTANE | 0.10729776E-01 | 0.23071249E-01 |
| N-BUTANE | 0.72590796E-01 | 0.14233592E 00 |
| I-PENTANE | 0.21675207E 00 | 0.28554976E 00 |
| N-PENTANE | 0.22798607E 00 | 0.28159198E 00 |
| HEXANE | 0.20393703E 00 | 0.16237965E 00 |
| HEPTANE | 0.13486491E 00 | 0.70542705E-01 |
| OCTANE | 0.54575715E-01 | 0.18366245E-01 |
| NONANE | 0.26691399E-01 | 0.58539726E-02 |
| DECANE | 0.51042349E-01 | 0.74233101E-02 |

| COMPONENT | STAGE NUMBER 13
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITRUGEN | 0.94186764E-11 | 0.16862076E-09 |
| H2S | 0.29088400E-04 | 0.13949067E-03 |
| CO2 | 0.10975901E-06 | 0.89818778E-06 |
| METHANE | 0.79135718E-07 | 0.80415754E-06 |
| ETHANE | 0.71428088E-06 | 0.52110887E-05 |
| PROPANE | 0.31517014E-03 | 0.10755956E-02 |
| I-BUTANE | 0.67466722E-02 | 0.15164362E-01 |
| N-BUTANE | 0.49114735E-01 | 0.10126925E 00 |
| I-PENTANE | 0.19461283E 00 | 0.27247272E 00 |
| N-PENTANE | 0.21251373E 00 | 0.28013063E 00 |
| HEXANE | 0.22828159E 00 | 0.19713345E 00 |
| HEPTANE | 0.15979411E 00 | 0.91991791E-01 |
| OCTANE | 0.63617480E-01 | 0.23966295E-01 |
| NONANE | 0.29851542E-01 | 0.74312692E-02 |
| DECANE | 0.55122160E-01 | 0.92182507E-02 |

| COMPONENT | STAGE NUMBER 14
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITRUGEN | 0.82648584E-12 | 0.14164476E-10 |
| H2S | 0.87458415E-05 | 0.42629395E-04 |
| CO2 | 0.19250339E-07 | 0.16402024E-06 |
| METHANE | 0.11731857E-07 | 0.11846633E-06 |
| ETHANE | 0.13687942E-06 | 0.10655698E-05 |
| PROPANE | 0.12576609E-03 | 0.45322131E-03 |
| I-BUTANE | 0.38502814E-02 | 0.92278866E-02 |
| N-BUTANE | 0.29905413E-01 | 0.66320440E-01 |
| I-PENTANE | 0.15694409E 00 | 0.23996828E 00 |
| N-PENTANE | 0.17793374E 00 | 0.25762356E 00 |
| HEXANE | 0.24082771E 00 | 0.23373852E 00 |
| HEPTANE | 0.19502998E 00 | 0.12890715E 00 |
| OCTANE | 0.83720652E-01 | 0.37116859E-01 |
| NONANE | 0.39781761E-01 | 0.11891831E-01 |
| DECANE | 0.71871706E-01 | 0.14708286E-01 |

| COMPONENT | STAGE NUMBER 15
LIQUID COMP. | VAPOUR COMP. |
|-----------|---------------------------------|----------------|
| NITROGEN | 0.77487824E-13 | 0.12286711E-11 |
| H2S | 0.24355673E-05 | 0.12134368E-04 |
| CO2 | 0.29562642E-08 | 0.27999772E-07 |
| METHANE | 0.17210124E-08 | 0.17107376E-07 |
| ETHANE | 0.22836665E-07 | 0.19811715E-06 |
| PROPANE | 0.43443123E-04 | 0.16997321E-03 |
| I-BUTANE | 0.18628813E-02 | 0.49175683E-02 |
| N-BUTANE | 0.15248629E-01 | 0.37776611E-01 |
| I-PENTANE | 0.10533938E 00 | 0.18466146E 00 |
| N-PENTANE | 0.12372376E 00 | 0.20705141E 00 |
| HEXANE | 0.21754068E 00 | 0.25334812E 00 |
| HEPTANE | 0.22058913E 00 | 0.18132232E 00 |
| OCTANE | 0.11577883E 00 | 0.66515464E-01 |
| NONANE | 0.65201760E-01 | 0.26137201E-01 |
| DECANE | 0.13466906E 00 | 0.38162326E-01 |

| Author | Title | Year |
|------------------------|---|------|
| 1. J. H. Van der Meer | 1. The Role of the State in the Development of the Economy | 1978 |
| 2. J. H. Van der Meer | 2. The Role of the State in the Development of the Economy | 1979 |
| 3. J. H. Van der Meer | 3. The Role of the State in the Development of the Economy | 1980 |
| 4. J. H. Van der Meer | 4. The Role of the State in the Development of the Economy | 1981 |
| 5. J. H. Van der Meer | 5. The Role of the State in the Development of the Economy | 1982 |
| 6. J. H. Van der Meer | 6. The Role of the State in the Development of the Economy | 1983 |
| 7. J. H. Van der Meer | 7. The Role of the State in the Development of the Economy | 1984 |
| 8. J. H. Van der Meer | 8. The Role of the State in the Development of the Economy | 1985 |
| 9. J. H. Van der Meer | 9. The Role of the State in the Development of the Economy | 1986 |
| 10. J. H. Van der Meer | 10. The Role of the State in the Development of the Economy | 1987 |
| 11. J. H. Van der Meer | 11. The Role of the State in the Development of the Economy | 1988 |
| 12. J. H. Van der Meer | 12. The Role of the State in the Development of the Economy | 1989 |
| 13. J. H. Van der Meer | 13. The Role of the State in the Development of the Economy | 1990 |
| 14. J. H. Van der Meer | 14. The Role of the State in the Development of the Economy | 1991 |
| 15. J. H. Van der Meer | 15. The Role of the State in the Development of the Economy | 1992 |
| 16. J. H. Van der Meer | 16. The Role of the State in the Development of the Economy | 1993 |
| 17. J. H. Van der Meer | 17. The Role of the State in the Development of the Economy | 1994 |
| 18. J. H. Van der Meer | 18. The Role of the State in the Development of the Economy | 1995 |
| 19. J. H. Van der Meer | 19. The Role of the State in the Development of the Economy | 1996 |
| 20. J. H. Van der Meer | 20. The Role of the State in the Development of the Economy | 1997 |

Table Of Subroutines

| | | | |
|------|---------------|----------------|---|
| (1) | <u>CHSEFC</u> | <u>AIINPUT</u> | Reads in the problem description and the Chao-Seader input data for the Thiele-Geddes program. |
| (2) | | <u>AOUTPT</u> | Outputs the calculated results of the Thiele-Geddes rigorous program. |
| (3) | | <u>BERGAM</u> | Is the modified Bergamini's calculational procedure mainline program written in subroutine form for use with the short cut design program. |
| (4) | | <u>BINPUT</u> | Reads in the problem description and the Chao-Seader input data for modified Bergamini's calculational procedure program. |
| (5) | | <u>BOUTPT</u> | Outputs the calculated results of the modified Bergamini's calculational procedure program. |
| (6) | | <u>BPHYS</u> | Calculates the Chao-Seader input data for hypothetical components in the modified Bergamini's calculational procedure program using the modified Cavett's correlation. Enthalpy input data is also calculated for the hypothetical components from the enthalpy correlation by Erbar. |
| (7) | | <u>BUBPT</u> | Calculates the bubble point temperature and compositions using the Chao-Seader K-ratios. |
| (8) | | <u>CFLOWR</u> | Calculates the column material balances for all the stages in the Thiele-Geddes program. |
| (9) | | <u>COMP</u> | Calculates the stage compositions for all the stages in the column in the Thiele-Geddes program. |
| (10) | | <u>CTEMP</u> | Is the stage temperature calculating subroutine used in the modified Bergamini's calculational procedure program. |
| (11) | | <u>DEWPT</u> | Calculates the dew point temperature and compositions using the Chao-Seader K-ratios. |
| (12) | | <u>DISTIL</u> | Computes the distillate temperature and enthalpy according to the specification of a total or a partial condenser. |

- | | | |
|------|---------------|---|
| (13) | <u>FEED</u> | Proceeds in the calculation for the feed condition according to the specifications for the particular problem. |
| (14) | <u>FLASH</u> | Calculates the flash compositions and temperature or fraction liquid according to the specifications of a constant temperature or a constant fraction liquid flash. |
| (15) | <u>GEDDES</u> | Is the Thiele-Geddes calculational procedure mainline program written in subroutine form for use with the short cut design program. |
| (16) | <u>GOLDIT</u> | Is a general golden section search subroutine programmed according to the procedure described by Wilde. It is used to solve for the root "theta" in the Underwood equation. |
| (17) | <u>HVAL</u> | Calculates flow stream enthalpies from the partial molar enthalpy values calculated from the correlation as proposed by Edmister and Erbar. |
| (18) | <u>INTERP</u> | Is a linear three dimensional interpolation scheme for the Erbar and Maddox charts for the column theoretical stage requirement. |
| (19) | <u>IN1TRP</u> | Is Lagrangian third order polynomial three dimensional interpolation scheme for the Erbar and Maddox charts for the column theoretical stage requirement. |
| (20) | <u>IN2PUT</u> | Reads in the Erbar and Maddox charts in the form of a twenty-one point three dimensional grid. This data is used in the interpolation subroutines INTERP and IN1TRP. |
| (21) | <u>KVAL</u> | Computes the Chao-Seader composition dependent K-ratios. |
| (22) | <u>K1VAL</u> | Calculates the Chao-Seader liquid fugacity coefficients which are equivalent to the pure component ideal K-ratios, requiring the ideal solution and ideal gas assumptions. |
| (23) | <u>PHYS</u> | Calculates the Chao-Seader input data for hypothetical components using the modified Cavett's correlation in the Thiele-Geddes program. Enthalpy |

lpy input data is also calculated for the hypothetical components from the enthalpy data correlation used by Erbar.

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|------|--------------------|---|
| (24) | \$IBFTC <u>PSY</u> | Determines the slope for the assumed linear relationship of log K-ratio vs temperature. This slope is then used in the subroutine CTEMP for the stage temperature correction in the modified Bergamini's calculational procedure program. |
| (25) | <u>SINPUT</u> | Reads in the problem description and the Chao-Seader input data for the short cut design computer program. |
| (26) | <u>SOUTPT</u> | Outputs the calculated results of the short cut design computer program. |
| (27) | <u>SPHYS</u> | Calculates the Chao-Seader input data for hypothetical components in the short cut design program using the modified Cavett's correlation. Enthalpy data for the hypothetical components is calculated from the enthalpy correlation used by Erbar. |
| (28) | <u>SRICUT</u> | Is the Fenske-Underwood-Erbar and Maddox short cut design combination computer program. It is written specifically for the design specification of the split on two components. |
| (29) | <u>TEMP</u> | Is the "bubble point" temperature calculation subroutine used with the Thiele-Geddes program. |
| (30) | <u>THETA</u> | Calculates the Theta convergence for the column using Newton's method. |
| (31) | <u>VLETEST</u> | Tests the variation of the vapour profiles in between the iterative column calculations and controls the values of the enthalpy profile assumed for the next trial. |
| (32) | <u>VPLQP</u> | Solves the column stage enthalpy balance equations starting at the bottom up the column for the column vapour-liquid flow rates in the Thiele-Geddes program. |

- (33) \$IBFTC VIIIF Solves the column stage enthalpy balance equations, calculating from both ends of the column towards the feed stage, for the column vapour-liquid flow rates in the Thiele-Geddes program.

ISN

SOURCE STATEMENT

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0 $IBFTC AINPUT  NODECK
1     SUBROUTINE AINPUT (NC,NHC,XMT)
C     ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C     ***** INPUT DATA FOR THIELE GEDDES CALCULATION IS READ IN *****
2     COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1A AOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3     COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4     COMMON/THREE/ JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5     COMMON/FIVE/ REFXR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
6     DIMENSION XMT(20,2)
7     2 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
10    3 FURMAT(1X, E14.7)
11    4 FORMAT(1X,4E14.7)
12    18 FORMAT(1X, 5I3,2F8.5,4F8.2,I3)
13    19 FORMAT(1X,F8.5,7I3)
14    100 FORMAT (8F10.6)
15    READ(5,18) NC,NHC,NTP,NFP,JX,REFXR,DIST,TD,P,TF,TW,JXX
24    READ(5,19) FRC,JA1,JA2,JA3,JA4,JA5,JA6,JA7
34    DO 1 I=1,NC
35    READ(5,2) CT(I),PC(I),W(I),DELTA(I),V1(I),(XMT(I,J),J=1,2)
42    READ (5,3) FX(I)
43    1 READ(5,4)(AA(J,1),J=1,4)
51    READ(5,100)((A(I,J),I=1,16),J=1,6 )
62    RETURN
63    END

```

1. Introduction

2. Methodology

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3. Results and Discussion

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4. Conclusion

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19. Appendix

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20. Bibliography

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21. Appendix

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ISN

SOURCE STATEMENT

```

0 $IBFTC AOUTPT NODECK
1 SUBROUTINE AOUTPT (DQC,DQR,XMT)
C ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C ***** PRINTOUT OF THIELE-GEDDES CALCULATIONS
2 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3 COMMON/FOUR/ AVP(50),ALP(50),T(50)
4 COMMON/FIVE/ REF XR, BXI(20),DXI(20),TD,TW,TF,FX(20)
5 DIMENSION XMT(20,2)
6 30 FORMAT(1HS,9X,13HREFLUX RATIO=,F8.5, 2X,16HDISTILLATE RATE=,F8.5,
1 2X ,14HFEED PLATE NO=,I3)
7 31 FORMAT(1X,9X,5HSTAGE,12X,6HVAPOUR,12X,6HLIQUID,10X,11HTEMPERATURE)
10 32 FORMAT(1X,9X,I4,12X,F8.5,12X,F8.5,12X,F8.3)
11 33 FORMAT(1X,5X,9HCOMPONENT,5X,10H FEED ,10X,10HDISTILLATE, 7X,10
1H BOTTOMS )
12 34 FORMAT(1X,4X,2A6,3X,E15.8, 5X,E15.8, 5X,E15.8)
13 35 FORMAT(1HL,25X,12HSTAGE NUMBER,2X,I3)
14 36 FORMAT(1X,7X,2A6,8X, E15.8,14X,E15.8)
15 37 FORMAT(1X,5X,9HCOMPONENT,15X,12HLIQUID COMP.,15X,12HVAPOUR COMP. )
16 3 FORMAT (1H2)
17 40 FORMAT(1HS,15X,16HDISTILLATE TEMP=,F8.3, 5X,25HNO OF THEORETICAL P
1LATES=,I4)
20 41 FORMAT(1HS,25X,30HCOMPOSITIONS IN MOLE FRACTIONS)
21 50 FORMAT (1HS,25X,22HBASIS ONE LB-MOLE FEED)
22 51 FORMAT (1HL,10X,20HCONDENSER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
1ED )
23 52 FORMAT (1HL,10X,20HREBOILER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
1ED )
24 53 FORMAT (1HS,20X,36HTHIELE GEDDES CALCULATION PROCEEDURE)
25 60 FORMAT (1HS,25X,16HCOLUMN PRESSURE=,F8.3,5H PSIA)
26 WRITE(6,3)
27 WRITE(6,53)
30 WRITE(6,50)
31 WRITE(6,60) P
32 WRITE(6,40) TD,NTP
33 WRITE(6,30)REFXR,DIST,NFP
34 WRITE(6,31)
35 DO 29 N=1,NTP
36 29 WRITE(6,32)N,AVP(N),ALP(N),T(N)
40 WRITE(6,51) DQC
41 WRITE(6,52) DQR
42 WRITE(6,3)
43 WRITE(6,41)
44 WRITE(6,33)
45 DO 401 I=1,NCP
46 401 WRITE(6,34) (XMT(I,J),J=1,2),FX(I),DXI(I),BXI(I)
54 M=3
55 WRITE(6,3)
56 DO 22 N=1,NTP
57 IF(N.EQ.M) GO TO 10
62 GO TO 11
63 10 WRITE(6,3)
64 M=M+2
65 11 CONTINUE
66 WRITE(6,35) N
67 WRITE(6,37)

```


ISN SOURCE STATEMENT

```
70      DU 22 I=1,NCP
71      22 WRITE(6,36) (XMT(I,J),J=1,2),X(N,I),Y(N,I)
100     RETURN
101     END
```

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SOURCE STATEMENT

```

0  $IBFTC BERGAM NUDECK
1      SUBROUTINE BERGAM (DI,BI,XFI,YFI,HXX,SFBI,DQC,DQR)
C          BERGAMINI CALCULATION PROCEEDURE
C          CHAU-SEADER K AND H VALUES
C          THETA CONVERGENCE METHOD
C  AVERAGEING TEMP AND LIQUID-VAPOUR PROFILES AS CONVERGENCE FORCEING
C  LIMIT LIQ-VAPOUR PROFILE TO 10 PERCENT CHANGE
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
IAAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      COMMON/FOUR/AVP(50),ALP(50),T(50)
6      COMMON/FIVE/ REF XR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
7      DIMENSION TA(5),V(20),BIDI(20),DI(20),BI(20),XX(20),YY(20),KKK(50)
10     DIMENSION XFI(20),YFI(20),XD(20),YD(20),PSI(51,20)
11     DIMENSION AVP1(50),ALP1(50),TT(50)
12     DIMENSION XMT(20,2)
13     REAL LO(20),L(50,20),LX(20)
14     6 FORMAT (1X,10X,5E13.6)
15     17 FORMAT (1X,10X,E13.6)
16     KXX=1
17     KXN=1
20     BOT=1.0-DIST
21     DO 222 N=1,NTP
22     222 KKK(N)=1
C
C          CALCULATION OF ASSUMED LINEAR TEMPERATURE PROFILE
C
24     CON=NTP
25     DEL=(TW-TD)/CON
26     TD=TD+459.6
27     T(1)=TD+DEL
30     DO 10 N=2,NTP
31     10 T(N)=T(N-1)+DEL
33     WRITE(6,17) SFBI
C
C          CALCULATION OF ASSUMED LINEAR VAPOUR AND LIQUID PROFILES
C
34     M=NFP-1
35     DO 8 N=1,M
36     ALP(N)=REFXR*DIST
37     8 AVP(N)=(REFXR+1.)*DIST
41     M=NTP-1
42     DO 9 N=NFP,M
43     ALP(N)=ALP(NFP-1)+FRAC
44     9 AVP(N)=AVP(NFP-1)-(1.-FRAC)
46     AVP(NTP)=AVP(NFP-1)-(1.-FRAC)
47     ALP(NTP)=BOT
C
C          STORAGE OF L-V-T PROFILES TO CHECK WITH NEWLY CALCULATED ONES
C
50     DO 131 N=1,NTP
51     ALP1(N)=ALP(N)
52     AVP1(N)=AVP(N)
53     131 TT(N)=T(N)

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SOURCE STATEMENT

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CALC OF CONDENSER CONDITION AND CONDENSER-REBUILER HEAT LOADS

```

55      GO TO (69,51),JXX
56      61 CALL KIVAL (NTP+1 ,TD,3)
57      DFRAC=REFXR/(REFXR+1.)
60      DO 62 I=1,NCP
61      YD(I)=DXI(I)
62      XD(I)=DXI(I)/VAP(I)
63      62 Y(1,I)=DFRAC*XD(I)+(1.-DFRAC)*YD(I)
65      GO TO 70
66      69 DO 777 I=1,NCP
67      777 Y(1,I)=DXI(I)
71      70 CALL KIVAL (1,T(1),1)
72      CALL KVAL (T(1),1)
73      DO 753 I=1,NCP
74      753 X(1,I)=Y(1,I)/VAP(I)
76      60 DO 75 I=1,NCP
77      75 XX(I)=DXI(I)
101     CALL DISTIL (TD,XX,SHDI,HDI,NTP+1,YD,XD,REFXR,HDX,HDI,T(1))
102     CALL BUBPT (BXI,T(NTP),NTP)
103     DO 938 I=1,NCP
104     938 XX(I)=X(NTP,I)
106     CALL HVAL (T(NTP),YY,XX ,2,NTP)
107     SHBI=HLIQ
110     DQC=(HDI-SHDI)*DIST*(REFXR+1.)
111     GO TO (30,31),JXX
112     30 DXD=SHDI
113     GO TO 32
114     31 DXD=HDI
115     32 DQR= DXD *DIST+SHBI*(1.-DIST)-SHFI+DQC
116     WRITE(6,17) DQC
117     WRITE(6,17) DQR
120     GO TO(80,81),JXX
121     80 HD=DIST*SHDI
122     GO TO 82
123     81 HD=DIST*HDI
124     82 CONTINUE
125     HB=SHBI*BUT

```

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CALCULATING UP COLUMN FROM BOTTOM, ENTHALPY AND MASS BALLANCES
AND SIMULTANEDUSLY CALCULATING NEW TEMPERATURES AND L-V PROFILES

```

126     DO 327 I=1,NCP
127     327 L(NTP-1,I)=AVP(NTP)*Y(NTP,I)+BI(I)
131     DO 714 I=1,NCP
132     714 L(NTP,I)=BOT*BXI(I)
134     MM=NTP
135     KF=NTP-NFP
136     DO 1000 NN=1,KF
137     N=MM-NN
140     K=1
141     K1=1
142     KK=1
143     TA(K)=T(N)

```


| ISN | SOURCE STATEMENT |
|-----|--|
| 144 | 668 CONTINUE |
| 145 | IF(K1.LE.2) GO TO 313 |
| 150 | IF(N.EQ.NFP) GO TO 313 |
| 153 | IF(KXX.EQ.1) GO TO 313 |
| 156 | DO 802 I=1,NCP |
| 157 | 802 YY(I)=Y(N,I) |
| 161 | CALL HVAL (T(N),YY,XX,1,N) |
| 162 | HV=HVAP |
| 163 | CALL HVAL (T(N-1),YY,YY,2,N-1) |
| 164 | HL=HLIQ |
| 165 | CALL HVAL (T(N-1),YY,BI,2,N-1) |
| 166 | HT=HLIQ |
| 167 | AVP(N)=(HT-HB+DQR)/(HV-HL) |
| 170 | CALL VLTEST (AVP,AVP1,N) |
| 171 | ALP(N-1)=AVP(N)+BOT |
| 172 | 313 SUMY=0. |
| 173 | K1=3 |
| 174 | SUMX=0. |
| 175 | DO 314 I=1,NCP |
| 176 | 314 SUMX=SUMX+L(N,I) |
| 200 | DO 803 I=1,NCP |
| 201 | 803 X(N,I)=L(N,I)/SUMX |
| 203 | TX=T(N) |
| 204 | IF(KKK(N).GT.2) GO TO 670 |
| 207 | CALL K1VAL (N,TX,2) |
| 210 | KKK(N)=3 |
| 211 | 670 CALL KVAL (TX,N) |
| 212 | DO 672 I=1,NCP |
| 213 | 672 AK(K,I)=VAP(I) |
| 215 | DO 671 I=1,NCP |
| 216 | 671 SUMY=SUMY+L(N,I)*AK(K,I) |
| 220 | DO 316 I=1,NCP |
| 221 | 316 Y(N,I)=L(N,I)*AK(K,I)/SUMY |
| 223 | IF(N.EQ.NFP) GO TO 972 |
| 226 | DO 315 I=1,NCP |
| 227 | 315 L(N-1,I)=AVP(N)*X(N,I)*AK(K,I)+BI(I) |
| 231 | GO TO 973 |
| 232 | 972 DO 974 I=1,NCP |
| 233 | 974 LX(I)=AVP(NFP)*Y(N,I)+BI(I) |
| 235 | 973 XR=SUMX/SUMY |
| 236 | IF(KK.GT.2)GO TO 317 |
| 241 | CALL PSY (TA(K),K,N,PSI) |
| 242 | KK=3 |
| 243 | 317 CALL CTEMP (TA,TZ,K,N,XR,PSI) |
| 244 | IF(K.LT.3) GO TO 668 |
| 247 | T(N)=TZ |
| 250 | 1000 CONTINUE |

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CALCULATING DOWN COLUMN FROM TOP , ENTHALPY AND MASS BALLANCES
AND SIMULTANEDOUSLY CALCULATING NEW TEMPERATURES AND L-V PROFILES

| | |
|-----|-----------------|
| 252 | DO 2000 N=1,NFP |
| 253 | K=1 |
| 254 | K1=1 |
| 255 | KK=1 |

| ISN | SOURCE STATEMENT |
|-----|---|
| 256 | TA(K)=T(N) |
| 257 | 667 CONTINUE |
| 260 | IF(N.EQ.NFP) GO TO 907 |
| 263 | IF(N.EQ.1) GO TO 302 |
| 266 | IF(K1.LE.2) GO TO 333 |
| 271 | 907 CONTINUE |
| 272 | IF(KXX.EQ.1) GO TO 911 |
| 275 | DO 801 I=1,NCP |
| 276 | 801 XX(I)=X(N-1,I) |
| 300 | CALL HVAL (T(N-1),YY,XX,2,N-1) |
| 301 | HL=HLIN |
| 302 | IF(N.EQ.NFP) GO TO 909 |
| 305 | GO TO 910 |
| 306 | 909 CALL HVAL (TF,XX,XX,1,N+2) |
| 307 | HH=HVAP |
| 310 | CALL HVAL (T(NFP),XX,XX,1,NFP) |
| 311 | HHH=HVAP |
| 312 | HV=(HH*(1.-FRAC)+HHH*AVP(NFP))/((1.-FRAC)+AVP(NFP)) |
| 313 | CALL HVAL (TF,DI,XX,1,N+2) |
| 314 | HH=HVAP |
| 315 | CALL HVAL (T(NFP),DI,XX,1,NFP) |
| 316 | HHH=HVAP |
| 317 | HT=(HH*(1.-FRAC)+HHH*AVP(NFP))/((1.-FRAC)+AVP(NFP)) |
| 320 | ALP(N-1)=(DQC+HD-HT)/(HV-HL) |
| 321 | AVX=ALP(N-1)+DIST |
| 322 | AVP(NFP)=AVX-1.+FRAC |
| 323 | GO TO 911 |
| 324 | 910 CONTINUE |
| 325 | CALL HVAL (T(N),XX,XX,1,N) |
| 326 | HV=HVAP |
| 327 | CALL HVAL (T(N),DI,XX,1,N) |
| 330 | HT=HVAP |
| 331 | ALP(N-1)=(DQC+HD-HT)/(HV-HL) |
| 332 | CALL VLTEST (ALP,ALP1,N-1) |
| 333 | AVP(N)=ALP(N-1)+DIST |
| 334 | 911 DO 713 I=1,NCP |
| 335 | 713 L(N-1,I)=X(N-1,I)*ALP(N-1) |
| 337 | IF(N.EQ.NFP) GO TO 2000 |
| 342 | GO TO 333 |
| 343 | 302 CONTINUE |
| 344 | IF (K.EQ.2) GO TO 663 |
| 347 | AVP(1)=DIST*REFXR+DIST |
| 350 | GO TO (67,68),JXX |
| 351 | 67 DO 754 I=1,NCP |
| 352 | 754 LO(I)=DI(I)*REFXR |
| 354 | GO TO 755 |
| 355 | 68 DO 300 I=1,NCP |
| 356 | 300 LO(I)=XD(I)*REFXR*DIST |
| 360 | 755 DO 756 I=1,NCP |
| 361 | 756 V(I)=LO(I)+DI(I) |
| 363 | 333 SUMY=0. |
| 364 | K1=3 |
| 365 | IF(N.EQ.1) GO TO 305 |
| 370 | DO 335 I=1,NCP |
| 371 | 335 V(I)=L(N-1,I)+DI(I) |

| ISN | SOURCE STATEMENT |
|-----|---|
| 373 | 305 DO 334 I=1,NCP |
| 374 | 334 SUMY=SUMY+V(I) |
| 376 | DO 821 I=1,NCP |
| 377 | 821 Y(N,I)=V(I)/SUMY |
| 401 | 663 TX=TA(K) |
| 402 | IF(KKK(N).GT.2) GO TO 664 |
| 405 | CALL KIVAL (N,IX,1) |
| 406 | KKK(N)=3 |
| 407 | 664 CALL KVAL (TX,N) |
| 410 | DO 665 I=1,NCP |
| 411 | 665 AK(K,I)=VAP(I) |
| 413 | SUMX=0. |
| 414 | DO 666 I=1,NCP |
| 415 | 666 SUMX=SUMX+V(I)/AK(K,I) |
| 417 | DO 336 I=1,NCP |
| 420 | X(N,I)=V(I)/AK(K,I)/SUMX |
| 421 | 336 L(N,I)=X(N,I)*ALP(N) |
| 423 | XR=SUMX/SUMY |
| 424 | IF(KK.GT.2) GO TO 337 |
| 427 | CALL PSY (TA(K),K,N,PSI) |
| 430 | KK=3 |
| 431 | 337 CALL CTEMP (TA,TZ,K,N,XR,PSI) |
| 432 | IF(K.LT.3) GO TO 667 |
| 435 | T(N)=TZ |
| 436 | 2000 CONTINUE |
| 440 | IF(KXX.EQ.1) GO TO 42 |
| 443 | DO 411 I=1,NCP |
| 444 | 411 YY(I)=Y(NTP,I) |
| 446 | CALL HVAL (T(NTP),YY,XX,1,NTP) |
| 447 | HHH=HVAP |
| 450 | DO 412 I=1,NCP |
| 451 | 412 XX(I)=X(NTP,I) |
| 453 | CALL HVAL (T(NTP),YY,XX,2,NTP) |
| 454 | HH=HLIQ |
| 455 | DO 413 I=1,NCP |
| 456 | 413 XX(I)=X(NTP-1,I) |
| 460 | CALL HVAL (T(NTP-1),YY,XX,2,NTP-1) |
| 461 | H=HLIQ |
| 462 | AVP(NTP)=(BOT*(HH-H)-DQR)/(H-HHH) |
| 463 | ALP(NTP-1)=AVP(NTP)+BOT |
| C | |
| C | FEED PLATE MISMATCH INCORPORATING THETA METHOD OF CONVERGENCE |
| C | SETS THE CORRECTION FOR THE NEXT ITERATION |
| C | |
| 464 | 42 SUMDI=0. |
| 465 | DO 109 I=1,NCP |
| 466 | GO TO (121,122,123,123),JX |
| 467 | 121 C1=1. |
| 470 | C2=0. |
| 471 | GO TO 120 |
| 472 | 122 C1=0. |
| 473 | C2=1.0 |
| 474 | GO TO 120 |
| 475 | 123 C1=FRAC*XF1(I)/FX(I) |
| 476 | C2=(1.-FRAC)*YF1(I)/FY(I) |

| ISN | SOURCE STATEMENT |
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| 477 | 120 $BIDI(I) = (L(NFP-1, I) / DI(I) + C1) / (LX(I) / BI(I) - 1. + C2)$ |
| 500 | $DI(I) = FX(I) / (1.0 + BIDI(I))$ |
| 501 | 109 $SUMDI = SUMDI + DI(I)$ |
| 503 | $DEL1 = (DIST - SUMDI)$ |
| 504 | WRITE(6,17) DEL1 |
| C | CONVERGENCE CRITERION |
| 505 | IF(KXN.LE.2) GO TO 15 |
| 510 | IF(ABS(DEL1).LE.1.0E-04.AND.ABS(1.-THET1).LE.1.0E-03) GO TO 400 |
| 513 | 15 CONTINUE |
| C | THETA CONVERGENCE |
| 514 | CALL THETA (THET1,FX,BIDI) |
| 515 | 41 FORMAT(1X,6X,18H THETA CONVERGENCE=,F8.5) |
| 516 | WRITE(6,41) THET1 |
| 517 | DO 113 I=1,NCP |
| 520 | $DI(I) = FX(I) / (1. + THET1 * BIDI(I))$ |
| 521 | 113 $BI(I) = THET1 * BIDI(I) * DI(I)$ |
| 523 | $SUMDI = 0.$ |
| 524 | $SUMBI = 0.$ |
| 525 | DO 711 I=1,NCP |
| 526 | $SUMDI = SUMDI + DI(I)$ |
| 527 | 711 $SUMBI = SUMBI + BI(I)$ |
| 531 | DO 712 I=1,NCP |
| 532 | $DXI(I) = DI(I) / SUMDI$ |
| 533 | 712 $BXI(I) = BI(I) / SUMBI$ |
| C | |
| C | CHECK T-PROFILE TO DECIDE IF L-V CORRECTIONS ARE TO BE MADE |
| C | |
| 535 | KXX=0 |
| 536 | DO 415 N=1,NTP |
| 537 | IF(ABS(TT(N)-T(N)).LE.10.) GO TO 415 |
| 542 | KXX=1 |
| 543 | 415 CONTINUE |
| 545 | DO 416 N=1,NTP |
| 546 | $T(N) = (T(N) + TT(N)) / 2.0$ |
| 547 | 416 $TT(N) = T(N)$ |
| 551 | WRITE(6,14) |
| 552 | 14 FORMAT(1X,20X,23HNEW TEMPERATURE PROFILE) |
| 553 | WRITE(6,6) (T(N),N=1,NTP) |
| 560 | WRITE(6,16) |
| 561 | 16 FORMAT(1X,20X,18HNEW VAPOUR PROFILE) |
| 562 | WRITE(6,6) (AVP(N),N=1,NTP) |
| 567 | 351 FORMAT (1X,16H*** ERROR 07 ***,71HSPECIFICATIONS FOR D AND THETA N
NOT MET WITHIN 25 TRIALS OF L-V PROFILES) |
| 570 | IF(KXN.LE.25) GO TO 350 |
| 573 | WRITE(6,351) |
| 574 | GO TO 400 |
| 575 | 350 CONTINUE |
| 576 | IF(KXX.EQ.1) GO TO 60 |
| 601 | KXN=KXN+1 |
| 602 | GO TO 60 |
| 603 | 400 CONTINUE |
| 604 | DO 43 N=1,NTP |
| 605 | 43 $T(N) = T(N) - 459.6$ |
| 607 | $TD = TD - 459.6$ |
| 610 | RETURN |

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the image of a set $A \subseteq \mathbb{R}$ under f as $f(A) = \{f(x) \mid x \in A\}$. The preimage of a set $B \subseteq \mathbb{R}$ under f is $f^{-1}(B) = \{x \in \mathbb{R} \mid f(x) \in B\}$.

For any sets $A, B \subseteq \mathbb{R}$, we have $f(f^{-1}(B)) \subseteq B$ and $f^{-1}(f(A)) \supseteq A$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We say f is injective if $f(x) = f(y) \implies x = y$.

We say f is surjective if for every $y \in \mathbb{R}$, there exists $x \in \mathbb{R}$ such that $f(x) = y$.

We say f is bijective if it is both injective and surjective.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the range of f as $\text{Range}(f) = f(\mathbb{R})$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the domain of f as $\text{Domain}(f) = \mathbb{R}$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the graph of f as $\text{Graph}(f) = \{(x, f(x)) \mid x \in \mathbb{R}\}$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the level set of f at $y \in \mathbb{R}$ as $f^{-1}(\{y\})$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the restriction of f to a set $A \subseteq \mathbb{R}$ as $f|_A: A \rightarrow \mathbb{R}$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the composition of f and g as $g \circ f: \mathbb{R} \rightarrow \mathbb{R}$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the inverse of f as $f^{-1}: \text{Range}(f) \rightarrow \mathbb{R}$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the image of f as $\text{Image}(f) = \text{Range}(f)$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the preimage of f as $\text{Preimage}(f) = \text{Domain}(f)$.

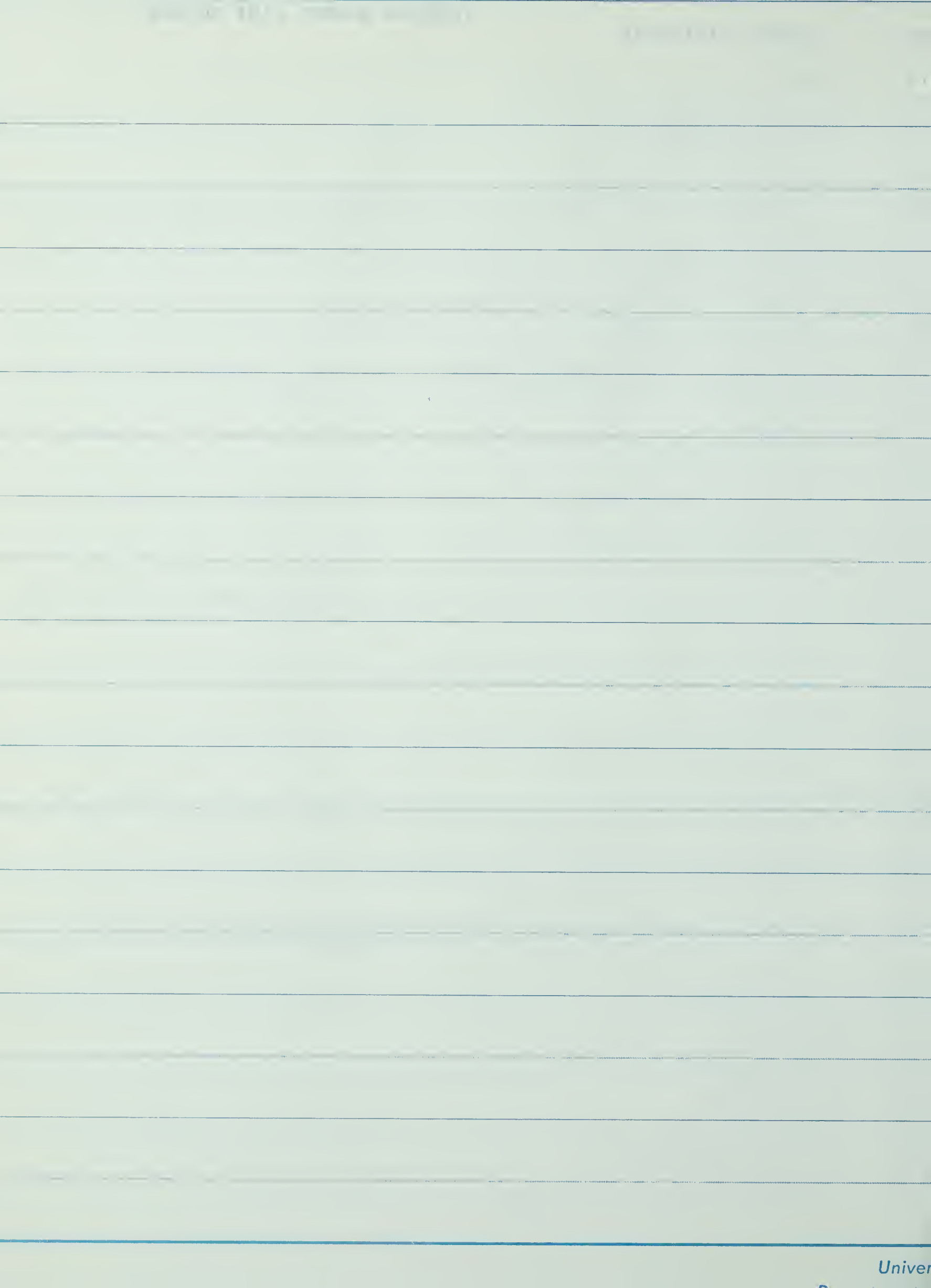
Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the kernel of f as $\text{Kernel}(f) = f^{-1}(\{0\})$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the image of f as $\text{Image}(f) = \text{Range}(f)$.

Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function. We define the preimage of f as $\text{Preimage}(f) = \text{Domain}(f)$.

| ISN | SOURCE STATEMENT |
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| 611 | END |
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SOURCE STATEMENT

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0 $IBFTC BINPUT  NODECK
1   SUBROUTINE BINPUT (NC,NHC,XMT)
C   ***** SUBROUTINE USED WITH BERGAMINI PROCEEDURE ONLY *****
C   ***** INPUT DATA FOR BERGAMINI CALCULATION IS READ IN *****
2   COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3   COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4   COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5   COMMON/FIVE/ REFXR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
6   DIMENSION XMT(20,2)
7   2 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
10  3 FORMAT(1X,3E14.7)
11  4 FORMAT(1X,4E14.7)
12  18 FORMAT(1X, 5I3,2F8.5,4F8.2,I3)
13  19 FORMAT(1X,F8.5,7I3)
14  100 FORMAT (8F10.6)
15  READ(5,18)NC,NHC,NTP,NFP,JX,REFXR,DIST,TD,P,TF,TW,JXX
24  READ(5,19) FRC,JA1,JA2,JA3,JA4,JA5,JA6,JA7
34  DO 1 I=1,NC
35  READ(5,2) CT(I),PC(I),W(I),DELTA(I),V1(I),(XMT(I,J),J=1,2)
42  READ (5,3) FX(I),DXI(I),BXI(I)
43  1 READ(5,4)(AA(J,I),J=1,4)
51  READ(5,100)((A(I,J),I=1,16),J=1,6 )
62  RETURN
63  END

```

| | |
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| 2. The second part of the document is a list of the titles of the papers presented at the conference. | |
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| 5. The fifth part of the document is a list of the conclusions of the papers presented at the conference. | |
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ISN

SOURCE STATEMENT

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0 $IBFTC BOUTPT NNODECK
1 SUBROUTINE BOUTPT (DQC,DQR,XMT)
C ***** SUBROUTINE USED WITH BERGAMINI PROCEEDURE ONLY *****
C ***** OUTPUT SUBROUTINE FOR BERGAMINI CALCULATION PROCEEDURE *****
2 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3 COMMON/FOUR/AVP(50),ALP(50),T(50)
4 COMMON/FIVE/ REFEXR, BXI(20),DXI(20),TD,TW,TF,FX(20)
5 DIMENSION XMT(20,2)
6 30 FORMAT(1HS,9X,13HREFLUX RATIO=,F8.5, 2X,16HDISTILLATE RATE=,F8.5,
1 2X ,14HFEED PLATE NO=,I3)
7 31 FORMAT(1X,9X,5HSTAGE,12X,6HVAPCUR,12X,6HLIQUID,10X,11HTEMPERATURE)
10 32 FORMAT(1X,9X,I4,12X,F8.5,12X,F8.5,12X,F8.3)
11 33 FORMAT(1X,5X,9HCOMPONENT,5X,10H FEED ,10X,10HDISTILLATE, 7X,10
1H BOTTOMS )
12 34 FORMAT(1X,4X,2A6,3X,E15.8, 5X,E15.8, 5X,E15.8)
13 35 FORMAT(1HL,25X,12HSTAGE NUMBER,2X,I3)
14 36 FORMAT(1X,7X,2A6,8X, E15.8,14X,E15.8)
15 37 FORMAT(1X,5X,9HCOMPONENT,15X,12HLIQUID COMP.,15X,12HVAPOUR COMP. )
16 3 FORMAT (1H2)
17 40 FORMAT(1HS,15X,16HDISTILLATE TEMP=,F8.3, 5X,25HNO OF THEORETICAL P
1LATES=,I4)
20 41 FORMAT(1HS,25X,30HCOMPOSITIONS IN MOLE FRACTIONS)
21 50 FORMAT (1HS,25X,22HBASIS ONE LB-MOLE FEED)
22 51 FORMAT (1HL,10X,20HCONDENSER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
1ED )
23 52 FORMAT (1HL,10X,20HREBOILER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
1ED )
24 53 FORMAT (1HS,20X,36H BERGAMINI CALCULATION PROCEEDURE )
25 60 FORMAT (1HS,25X,16HCOLUMN PRESSURE=,F8.3,5H PSIA)
26 WRITE(6,3)
27 WRITE(6,53)
30 WRITE(6,50)
31 WRITE(6,60) P
32 WRITE(6,40) TD,NTP
33 WRITE(6,30)REFEXR,DIST,NFP
34 WRITE(6,31)
35 DO 29 N=1,NTP
36 29 WRITE(6,32)N,AVP(N),ALP(N),T(N)
40 WRITE(6,51) DQC
41 WRITE(6,52) DQR
42 WRITE(6,3)
43 WRITE(6,41)
44 WRITE(6,33)
45 DO 401 I=1,NCP
46 401 WRITE(6,34) (XMT(I,J),J=1,2),FX(I),DXI(I),BXI(I)
54 M=3
55 WRITE(6,3)
56 DO 22 N=1,NTP
57 IF(N.EQ.M) GO TO 10
62 GO TO 11
63 10 WRITE(6,3)
64 M=M+2
65 11 CONTINUE
66 WRITE(6,35) N
67 WRITE(6,37)

```


ISN SOURCE STATEMENT

```
70 DO 22 I=1,NCP  
71 22 WRITE(6,36) (XMF(I,J),J=1,2),X(N,I),Y(N,I)  
100 RETURN  
101 END
```

$$\Phi(x) = \int_{-\infty}^x \phi(t) dt$$

ISN SOURCE STATEMENT

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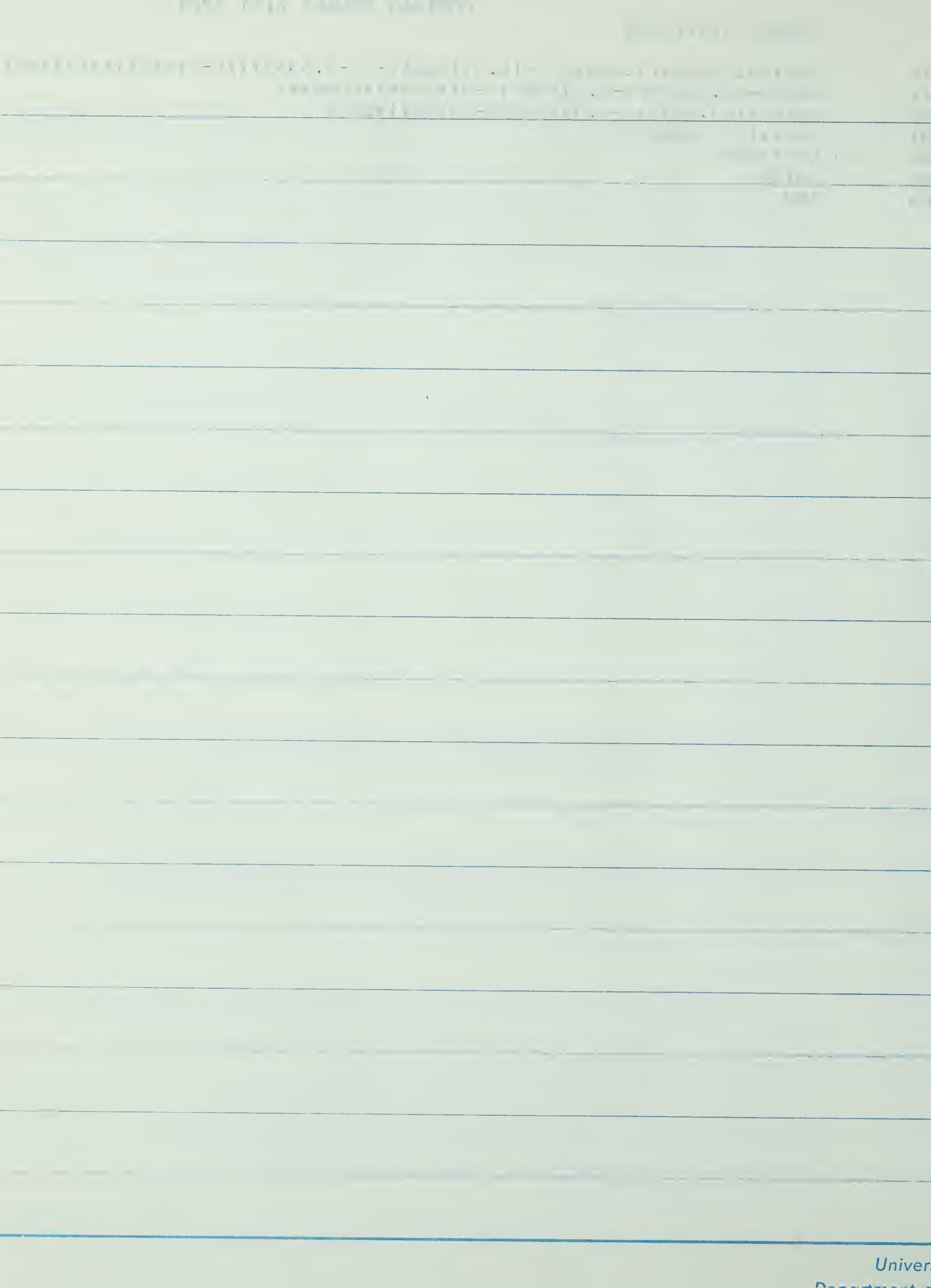
0 $IBFTC BPHYS
1 SUBROUTINE BPHYS (NC,XMT)
C ***** SUBROUTINE USED WITH BERGAMINI PROCEEDURE ONLY *****
C*** PHYSICAL PROPERTIES ARE CALCULATED IN THIS SUBROUTINE FOR HYPOTHETICAL
C*** COMPONENTS TO CALCULATE CHAU-SEADER K-RATIOS AND H-VALUES
C***** ----- CAVETTES METHOD -----
2 COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4 COMMON/THREE/ JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5 COMMON/FIVE/ REFXR, BXI(20),DXI(20),TD,TW,TF,FX(20)
6 DIMENSION XMT(20,2)
7 33 FORMAT(1X,3E14.7)
10 50 FORMAT(1X,7F8.3,11X,2A6)
11 M=NC+1
12 DO 20 I=M,NCP
13 READ(5,50)BPCA,BMLA,BPMNA,TC1,PC1,API,XXWM,(XMT(I,J),J=1,2)
20 READ (5,33) FX(I),DXI(I),BXI(I)
21 SPG=141.5/(API+131.5)
22 IF(BPMNA.EQ.0.) GO TO 1
25 GO TO 2
26 1 BPMNA=(BPCA+BMLA)/2.0
27 2 XRHO=0.98907*SPG
30 V1(I)=XXWM/XRHO
31 UOPK=((BPMNA+459.6)**(1.0/3.0))/SPG
32 IF(TC1.EQ.0.) GO TO 3
35 GO TO 4
36 3 IF(BMLA.EQ.0.) GO TO 9
41 BP=BMLA
42 GO TO 11
43 9 BP=BPMNA
44 11 CONTINUE
45 TC1=768.07121+(1.7133693-0.10834003E-02*BP )*BP
46 TC1=TC1-0.89212579E-02*API*BP +0.38890584E-06*BP **3
47 TC1=TC1+((0.53094920E-05+0.32711600E-07*API)*API)*BP **2
50 4 CT(I)=TC1
51 IF(PC1.EQ.0.) GO TO 5
54 GO TO 6
55 5 PC1=2.8290406+(0.94120109E-03-0.30474749E-05*BPMNA)*BPMNA
56 PC1=PC1-0.20876110E-04*API*BPMNA+0.15184103E-08*BPMNA**3
57 PC1=PC1+((+.11047890E-07+0.13949619E-09*API)*API)*BPMNA**2
60 PC1=PC1-0.48271599E-07*API**2*BPMNA
61 PC1=EXP (PC1*2.303)
62 6 PC(I)=PC1
63 BP=BPMNA+459.6
64 W(I)=(3.0/7.0)*((ALOG(PC1/14.696))/2.303)/(TC1/BP-1.0)-1.0
65 DEHV=(7.58+4.571*(ALOG(BP ))/2.303)*(BPMNA+459.6)/1.8
66 DEHV=DEHV*((TC1-537.)/(TC1-(BPMNA+459.6)))*0.38
67 DELTA(I) =((DEHV-592.4)/V1(I) ) **0.5
70 AA(3,I) =XXWM*(3.1073165E-04-5.832381E-08*API)
71 AA(4,I) =XXWM*(9.1745019E-11*API-5.6334748E-08)
72 HB=-.81862040+ (-2.8568654E-05+1.7024654E-06*API)*API
73 HB=HB-1.4886832E-08*API**3 -3.0836492E-04*UOPK**3
74 HB=HB+(8.8395563E-02+4.2934703E-03*UOPK)*UOPK
75 AA(2,I) =XXWM*HB

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76 HB=188.25000+(3.5442502-(5.2716944E-02-3.5353777E-04*API)*API)*API
77 HB=HB-(8.9530784-3.5118581E-01*UOPK)*UOPK**2
100 HB=HB+(43.401618-5.9563889E-03*API)*UOPK
101 AA(1,1) =XXWM*HB
102 20 CONTINUE
104 RETURN
105 END
```

| ISN | SOURCE STATEMENT |
|-----|---|
| 0 | BIBFTC BUBPT NODACK |
| 1 | SUBROUTINE BUBPT (XX, TX, N) |
| | C*** SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS *** |
| | C***** BUBBLE POINT IS CALCULATED |
| 2 | COMMON/ONE/ CT(20), PC(20), W(20), DELTA(20), V1(20), VAP(20), A(16,6), |
| | IAAOB(51), ZZ(51), BBMIX(51), DDELMX(51), HLIQ, HVAP |
| 3 | COMMON/TWO/ X(51,20), Y(51,20), P, NCP, NTP, NFP, BOT, DIST, AK(51,20) |
| 4 | COMMON/THREE/ JX, JA1, JA2, JA3, JA4, JA5, JA6, JA7, JXX, FRAC, FRC, AA(4,20) |
| 5 | DIMENSION XX(20) |
| 6 | 11 FORMAT (1X, 16H*** ERROR 04 ***, 42HBUBPT MORE THAN THIRTY TRIALS A |
| | 1RE REQUIRED) |
| 7 | DO 1 I=1, NCP |
| 10 | X(N, I)=XX(I) |
| 11 | 1 Y(N, I)=X(N, I) |
| 13 | K1=1 |
| 14 | 2 CALL KVAL (TX, N) |
| 15 | SUMY=0. |
| 16 | O=0.0 |
| 17 | DO 3 I=1, NCP |
| 20 | CON1=VAP(I)*XX(I) |
| 21 | IF(ABS(Y(N, I)-CON1).LE.1.0E-04) GO TO 4 |
| 24 | O=1.0 |
| 25 | 4 Y(N, I)=CON1 |
| 26 | 3 SUMY=SUMY+CON1 |
| 30 | IF(ABS(SUMY-1.0).GT.1.0E-04) GO TO 5 |
| 33 | IF(O.LE.1.0E-04) GO TO 10 |
| 36 | 5 DO 6 I=1, NCP |
| 37 | 6 Y(N, I)=Y(N, I)/SUMY |
| 41 | K1=K1+1 |
| 42 | IF(K1.GT.30) GO TO 9 |
| 45 | Q=TX*(1.0+(1.0-SUMY)/5.0) |
| 46 | IF(ABS(O-TX).LT.30.0) GO TO 8 |
| 51 | IF((SUMY-1.0).GE.0.) GO TO 7 |
| 54 | TX=TX+30.0 |
| 55 | GO TO 2 |
| 56 | 7 TX=TX-30.0 |
| 57 | GO TO 2 |
| 60 | 8 TX=Q |
| 61 | GO TO 2 |
| 62 | 9 WRITE (6, 11) |
| 63 | 10 CONTINUE |
| 64 | RETURN |
| 65 | END |

ISN

SOURCE STATEMENT

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0  $IBFTC CFLOWR  NUDECK
1  SUBROUTINE CFLOWR( ALIQ0)
C  ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C  ***** COMPONENT FLOW RATE RATIOS ARE CALCULATED
2  DIMENSION ALIQ0(20)
3  COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4  COMMON/FOUR/ AVP(50),ALP(50),T(50)
5  COMMON/SIX/ SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
6  M=NFP-1
7  DO 103 N=1,M
10  DO 103 I=1,NCP
11  103 ABF(N,I)=ALP(N)/(AK(N,I)*AVP(N))
14  K=NTP+1
15  MK=NTP-NFP+1
16  DO 104 N=1,MK
17  M=K-N
20  DO 104 I=1,NCP
21  104 ASF(M,I)=AK(M,I)*AVP(M)/ALP(M)
24  DO 105 I=1,NCP
25  105 ALIQ(1,I)=ABF(1,I)*(ALIQ0(I)+1.)
27  M=NFP-2
30  DO 106 N=1,M
31  DO 106 I=1,NCP
32  106 ALIQ(N+1,I)=ABF(N+1,I)*(ALIQ(N,I)+1.0)
35  DO 107 I=1,NCP
36  107 ALIQ(NTP,I)=1.0
40  K=NTP
41  KK=NTP-NFP
42  DO 108 N=1,KK
43  M=K-N
44  DO 108 I=1,NCP
45  108 ALIQ(M,I)=ALIQ(M+1,I)*ASF(M+1,I)+1.0
50  RETURN
51  END

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ISN SOURCE STATEMENT

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0 $IBFTC COMP      NDDCK
1      SUBROUTINE COMP (DI,BI)
C      ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C      *****      NORMALIZED STAGE COMPOSITIONS ARE CALCULATED
2      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3      COMMON/FOUR/ AVP(50),ALP(50),T(50)
4      COMMON/SIX/  SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
5      DIMENSION DI(20),BI(20)
6      M=NFP-1
7      DO 397 N=1,M
10     SUMLI=0.
11     DO 114 I=1,NCP
12     114 SUMLT=SUMLT+ALIQ(N,I)*DI(I)
14     DO 397 I=1,NCP
15     397 X(N,I)=ALIQ(N,I)*DI(I)/SUMLT
20     M=NTP-NFP+1
21     DO 398 N=1,M
22     MK=NTP+1-N
23     SUMLB=0.
24     DO 116 I=1,NCP
25     116 SUMLB=SUMLB+ALIQ(MK,I)*BI(I)
27     DO 398 I=1,NCP
30     398 X(MK,I)=ALIQ(MK,I)*BI(I)/SUMLB
33     DO 503 N=1,NTP
34     SUMY=0.
35     DO 504 I=1,NCP
36     504 SUMY=SUMY+X(N,I)*AK(N,I)
40     DO 503 I=1,NCP
41     503 Y(N,I)=X(N,I)*AK(N,I)/SUMY
44     RETURN
45     END

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ISN SOURCE STATEMENT

```

0 $IBFTC CTEMP
1 SUBROUTINE CTEMP (TA,TZ,K,N,XR,PSI)
C ***** SUBROUTINE USED WITH BERGAMINI PROCEEDURE ONLY *****
C ***** BERGAMINI TEMPERATURE CORRECTION PROCEEDURE *****
2 COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,3),
1AAGB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4 COMMON/THREE/ JX,JA,JB,JC,JD,JE,JXX,FRAC,FRC,AA(4,20)
5 DIMENSION TC(5),TA(5),PSI(51,20)
6 SUMTK=0.
7 DO 306 I=1,NCP
10 XRK =AK(K,I)*XR
11 TK =TA(K)+(ALOG10(XRK )-ALOG10(AK(K,I)))/PSI(N,I)
12 306 SUMTK=SUMTK+X(N,I)*TK
14 TC(K)=SUMTK
15 TA(K+1)=TA(K)+(TC(K)-TA(K))/2.
16 IF(ABS(TC(K)-TA(K)).LE.0.20) GO TO 307
21 IF(K.GE.2) GO TO 308
24 GO TO 18
25 307 TZ=TA(K+1)
26 GO TO 18
27 308 TZ=(TA(2)*TC(1)-TA(1)*TC(2))/(TA(2)+TC(1)-(TA(1)+TC(2)))
30 IF(XR.GE.1.0) GO TO 8
33 IF(TZ.GT.TA(K+1)) GO TO 9
36 TZ=TA(K+1)
37 GO TO 7
40 8 IF(TZ.LT.TA(K+1)) GO TO 9
43 TZ=TA(K+1)
44 GO TO 7
45 9 IF(ABS(TZ-TA(K+1)).LT.10.) GO TO 7
50 TZ=(TA(K+1)+TA(K))/2.0
51 7 CONTINUE
52 18 CONTINUE
53 K=K+1
54 RETURN
55 END

```


ISN

SOURCE STATEMENT

```

0 $IBFTC DEWPT  NODECK
1  SUBROUTINE DEWPT (YY, TX, N)
C ***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C  *****  DEW POINT IS CALCULATED
2  COMMON/ONE/  CT(20), PC(20), W(20), DELTA(20), V1(20), VAP(20), A(16,6),
1AAOB(51), ZZ(51), BBMIX(51), DDELMX(51), HLIQ, HVAP
3  COMMON/TWO/  X(51,20), Y(51,20), P, NCP, NTP, NFP, BOT, DIST, AK(51,20)
4  COMMON/THREE/ JX, JA1, JA2, JA3, JA4, JA5, JA6, JA7, JXX, FRAC, FRC, AA(4,20)
5  DIMENSION YY(20)
6  11 FORMAT (1X, 16H*** ERROR 03 ***, 42HDEWPT MORE THAN THIRTY TRIALS A
1RE REQUIRED )
7  DO 1 I=1, NCP
10  Y(N, I)=YY(I)
11  1 X(N, I)=Y(N, I)
13  K1=1
14  2 CALL KVAL (TX, N)
15  SUMX=0.
16  O=0.
17  DO 3 I=1, NCP
20  CON1=YY(I)/VAP(I)
21  IF (ABS(X(N, I)-CON1).LE.1.0E-04) GO TO 4
24  O=1.0
25  4 X(N, I)=CON1
26  3 SUMX=SUMX+CON1
30  IF (ABS(SUMX-1.0).GT.1.0E-04) GO TO 5
33  IF (O.LE.1.0E-04) GO TO 10
36  5 DO 6 I=1, NCP
37  6 X(N, I)=X(N, I)/SUMX
41  K1=K1+1
42  IF (K1.GT.30) GO TO 9
45  Q=TX*(1.0+(SUMX-1.0)/5.0)
46  IF (ABS(Q-TX).LT.30.) GO TO 8
51  IF ((SUMX-1.0).GE.0.) GO TO 7
54  TX=TX-30.0
55  GO TO 2
56  7 TX=TX+30.0
57  GO TO 2
60  8 TX=Q
61  GO TO 2
62  9 WRITE (6, 11)
63  10 CONTINUE
64  RETURN
65  END

```


ISN

SOURCE STATEMENT

```

0 $IBFTC DISTIL  NODCK
1 SUBROUTINE DISTIL (TD,XXX,SHDI,HDV,N,YD,XD,REFXR,HL,HV,T)
C*** SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C ***** DISTILLATE CONDITIONS ARE CALCULATED *****
2 DIMENSION XXX(20),YD(20),XD(20)
3 COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAUB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
4 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
5 COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
6 DIMENSION T(50)
7 TX=TD
10 TZ=T(1)
11 GO TO (5,6),JXX
12 5 CALL SUBPT (XXX,TX,N)
13 CALL HVAL (TX,YY,XXX,2,N )
14 SHDI=HLIQ
15 DO 8 I=1,NCP
16 8 XXX(I)=Y(1,I)
20 CALL HVAL (TZ ,XXX,XX,1,1)
21 HDV=HVAP
22 GO TO 7
23 6 DO 2 I=1,NCP
24 YD(I)=XXX(I)
25 Y(N,I)=YD(I)
26 2 XXX(I)=Y(1,I)
30 CALL HVAL (TZ ,XXX,XX,1,1)
31 HDV=HVAP
32 IX=1
33 CALL KIVAL (N,TX,1)
34 24 SUMX=0.
35 CK=0.
36 DO 10 I=1,NCP
37 CX=YD(I)/VAP(I)
40 IF((ABS(CX-XD(I))-1.0E-04).LE.0.0) GO TO 11
43 CK=1.0
44 11 XD(I)=CX
45 10 SUMX=SUMX+XD(I)
47 IF(IX.GT.30) GO TO 98
52 IX=IX+1
53 IF((ABS(SUMX-1.0)-1.0E-04).GT.0.0) GO TO 700
56 IF (CK.LE.0.0) GO TO 99
61 700 DO 16 I=1,NCP
62 16 XD(I)=XD(I)/SUMX
64 DO 27 I=1,NCP
65 27 X(N,I)=XD(I)
67 Q=TX*(1.0+(SUMX-1.0)/5.0)
70 IF((ABS(Q-TX)-30.0).LE.0.0) GO TO 21
73 IF((SUMX-1.0).GT.0.0) GO TO 22
76 TX=TX-30.
77 GO TO 200
100 22 TX=TX+30.
101 GO TO 200
102 21 TX=Q
103 200 CALL KVAL (TX,N)
104 GO TO 24

```


| ISN | SOURCE STATEMENT |
|-----|---|
| 105 | 98 WRITE(6,29) |
| 106 | 29 FORMAT (1X,16H*** ERROR 05 ***,47HMORE THAN THIRTY TRIALS ARE REQU
11RED FOR DISTIL) |
| 107 | 99 CONTINUE |
| 110 | CALL HVAL (IX,YD,XX,1,N) |
| 111 | HV=HVAP |
| 112 | CALL HVAL (IX,YY,XD,2,N) |
| 113 | HL=HLIQ |
| 114 | DFRAC=REFXR/(REFXR+1.) |
| 115 | SHDI=HV*(1.-DFRAC)+HL*DFRAC |
| 116 | 7 TD=TX |
| 117 | RETURN |
| 120 | END |

ISN

SOURCE STATEMENT

```

0 $IBFTC FEED      NODECK
1      SUBROUTINE FEED (TX,FX,XFI,YFI,N,SHFI,XMT)
C*** SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C*** FEED TEMPERATURE, ENTHALPY AND FEED CONDITION ARE CALCULATED
2      COMMON/ONE/ CT(20),PC(20),w(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      DIMENSION XFI(20),YFI(20),FX(20)
6      DIMENSION XMT(20,2)
7      6 FORMAT (1H2)
10     WRITE(6,6)
11     8 FORMAT (1HS,25X,14HFEED CONDITION)
12     WRITE(6,8)
13     GO TO (31,32,33,33),JX
14     31 CALL BUBPT (FX,TX,N)
15         TZ=TX-459.6
16         WRITE (6,12) TZ
17         CALL HVAL (TX,YY,FX,2,N)
20         SHFI=HLIQ
21         FRAC=1.0
22     12 FORMAT (1X,10X,14HHLIQ FEED TEMP=,F8.2,2H F,5X,12HSAT LIQ FEED)
23     GO TO 131
24     32 CALL DEWPT (FX,TX,N)
25         TZ=TX-459.6
26         WRITE (6,11) TZ
27         CALL HVAL (TX,FX,XX,1,N)
30         SHFI=HVAP
31     11 FORMAT (1X,10X,14HVVAP FEED TEMP=,F8.2,2H F,5X,12HSAT VAP FEED)
32         FRAC=0.0
33         GO TO 131
34     33 CALL FLASH (TX,FX,N,XMT,SHFI)
35         DO 3 I=1,NCP
36             XFI(I)=X(N,I)
37             3 YFI(I)=Y(N,I)
41         GO TO (131,131,132,132),JX
42     132 CALL HVAL (TX,YY,XFI,2,N)
43         H1=HLIQ
44         CALL HVAL (TX,YFI,XX,1,N)
45         H2=HVAP
46         SHFI=FRAC*H1+(1.-FRAC)*H2
47     131 CONTINUE
50         WRITE(6,6)
51         RETURN
52         END

```


ISN

SOURCE STATEMENT

```

0 $IBFTC FLASH  NODACK
1      SUBROUTINE FLASH (TX,X1,N,XMT,SHFI)
C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C**** FLASH TEMPERATURE AND CONDITION IS CALCULATED
C*****  CONSTANT TEMPERATURE FLASH OR CONSTANT FRACTION LIQUID SPEC.
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      DIMENSION X1(20)
6      DIMENSION XMT(20,2)
7      TZ=TX
10     IF(JX.EQ.3) GO TO 12
13     CALL BUBPT (X1,TX,N)
14     TL=TX
15     CALL HVAL (TZ,YY,X1,2,N)
16     HX=HLIQ
17     TX=TZ
20     CALL DEWPT (X1,TX,N)
21     TU=TX
22     CALL HVAL (TZ,X1,XX,1,N)
23     HV=HVAP
24     IF((TZ-TL).GT.0.0) GO TO 4
27     TX=TZ-459.6
30     WRITE(6,5) TX
31     JX=1
32     SHFI=HX
33     FRAC=1.0
34     5 FORMAT (1X,16H*** ERROR 09 ***,22H SPECIFIED TEMPERATURE,F8.2,2H F
1,5X,19H BELOW BUBBLE POINT)
35     GO TO 7
36     4 IF((TU-TZ).GT.0.0) GO TO 7
41     TX=TZ-459.6
42     WRITE(6,8) TX
43     JX=2
44     SHFI=HV
45     FRAC=0.
46     8 FORMAT (1X,16H*** ERROR 08 ***,22H SPECIFIED TEMPERATURE,F8.2,2H F
1,5X,16H ABOVE DEW POINT)
47     7 CONTINUE
50     GO TO (99,99,12,9),JX
51     9 FRAC=0.5
52     GO TO 13
53     12 FRAC=FRC
54     13 CALL KIVAL (N,TZ,3)
55     IX=0
56     IY=0
57     IZ=0
60     24 SUMY=0.
61     SUMX2=0.
62     SUMX=0.
63     SUMX1=0.
64     CK=0.
65     DO 10 I=1,NCP
66     CON1=1.0-VAP(I)

```


| ISN | SOURCE STATEMENT |
|-----|--|
| 67 | CON2=FRAC*CON1+VAP(1) |
| 70 | CX=X1(I)/CON2 |
| 71 | IF((ABS(CX-X(N,I))-1.0E-04).LE.0.0) GO TO 11 |
| 74 | CK=1.0 |
| 75 | 11 X(N,I)=CX |
| 76 | Y(N,I)=X(N,I)*VAP(I) |
| 77 | SUMX=SUMX+X(N,I) |
| 100 | SUMY=SUMY+Y(N,I) |
| 101 | O=X1(I)*CON1/CON2 |
| 102 | SUMX1=SUMX1+O |
| 103 | 10 SUMX2=SUMX2+O*CON1/CON2 |
| 105 | DO 16 I=1,NCP |
| 106 | X(N,I)=X(N,I)/SUMX |
| 107 | 16 Y(N,I)=Y(N,I)/SUMY |
| 111 | IX=IX+1 |
| 112 | IF(IX.GE.31) GO TO 98 |
| 115 | IF((ABS(SUMX1)-1.0E-04).GT.0.0) GO TO 17 |
| 120 | IF (CK.LE.0.) GO TO 99 |
| 123 | 17 IF(JX.EQ.3) GO TO 20 |
| 126 | CX=FRAC+SUMX1/SUMX2 |
| 127 | IF(CX.GT.0.) GO TO 14 |
| 132 | IF(IY.GE.10) GO TO 99 |
| 135 | IY=IY+1 |
| 136 | FRAC=FRAC/2.0 |
| 137 | GO TO 200 |
| 140 | 14 IF((CX-1.0).LT.0.0) GO TO 15 |
| 143 | IF(IZ.GE.10) GO TO 99 |
| 146 | IZ=IZ+1 |
| 147 | FRAC=(FRAC+1.0)/2.0 |
| 150 | GO TO 200 |
| 151 | 15 FRAC=CX |
| 152 | GO TO 200 |
| 153 | 20 Q=TZ*(1.0+SUMX1/5.0) |
| 154 | IF((ABS(Q-TZ)-30.0).LE.0.0) GO TO 21 |
| 157 | IF(SUMX1.GT.0.0) GO TO 22 |
| 162 | TZ=TZ-30. |
| 163 | GO TO 200 |
| 164 | 22 TZ=TZ+30. |
| 165 | GO TO 200 |
| 166 | 21 TZ=Q |
| 167 | 200 CALL KVAL (TZ,N) |
| 170 | GO TO 24 |
| 171 | 98 WRITE(6,29) |
| 172 | 29 FORMAT(1X,16H*** ERROR 01 ***,39HMORE THAN 30 TRIALS REQUIRED FOR
1FLASH) |
| 173 | 99 CONTINUE |
| 174 | 25 FORMAT(1X,10X,9HCOMPONENT, 8X,2HMF,3X,12HFLASH LIQUID, 8X, 2HMF,3
1X,12HFLASH VAPOUR) |
| 175 | 26 FORMAT(1X,9X,2A6,9X, E15.8,12X,E15.8) |
| 176 | 27 FORMAT(1HS,10X,11HFLASH TEMP=,F8.3,2H F, 5X,16HFRACTION LIQUID=,E1
15.8) |
| 177 | TX=TZ |
| 200 | TZ=TZ-459.6 |
| 201 | GO TO (300,301,302,302),JX |
| 202 | 302 WRITE(6,27) TZ,FRAC |

1941

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

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1.

| ISN | SOURCE STATEMENT |
|-----|---|
| 203 | WRITE(6,25) |
| 204 | DO 28 I=1,NCP |
| 205 | 28 WRITE(6,26) (XMT(I,J),J=1,2),X(N,I),Y(N,I) |
| 213 | RETURN |
| 214 | 300 WRITE(6,350) TZ |
| 215 | 350 FORMAT(1X,10X,15HLIQUID TEMP IS=,F8.2,2H F) |
| 216 | RETURN |
| 217 | 301 WRITE(6,351) TZ |
| 220 | 351 FORMAT(1X,10X,15HVAPOUR TEMP IS=,F8.2,2H F) |
| 221 | RETURN |
| 222 | END |

[Faint, illegible text from the reverse side of the page, appearing as bleed-through.]

ISN SOURCE STATEMENT

```

0 $IBFTC GEDDES  NODECK
1     SUBROUTINE GEDDES (DI,BI,XFI,YFI,HXX,SHFI,DQC,DQR)
C         THIELL-GEDDES CALCULATION PROCEEDURE
C         CHAO-SEADER K AND H VALUES
C     AVERAGEING TEMP AND LIQUID-VAPOUR PROFILES AS CONVERGENCE FORCEING
C         THETA CONVERGENCE METHOD
C         BOUNDARY SET ON THETA AND L-V PROFILES
C         V-PROFILE VARIES 10 PERCENT *****
2     COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3     COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4     COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5     COMMON/FOUR/ AVP(50),ALP(50),T(50)
6     COMMON/FIVE/ REFEXR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
7     COMMON/SIX/  SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
10    DIMENSION      TT(50),AVP1(50),DLOR(20),YD(20),XD(20),
1BIDI(20),DI(20),BI(20),XX(20),YY(20),ALIQ0(20),XFI(20),YFI(20)
11    DIMENSION XMT(20,2)
12    6 FORMAT (1X,10X,5E13.6)
13    17 FORMAT (1X,10X,E13.6)
14    KXX=1
15    KXN=1
16    BOT=1.0-DIST
C
C     CALCULATION OF ASSUMED LINEAR TEMPERATURE PROFILE
C
17    CON=NTP
20    DEL=(TW-TD)/CON
21    T(1)=TD+DEL
22    DO 10 N=2,NTP
23    10 T(N)=T(N-1)+DEL
C
C     CALCULATION OF ASSUMED LINEAR VAPOUR AND LIQUID PROFILES
C
25    M=NFP-1
26    DO 8 N=1,M
27    ALP(N)=REFEXR*DIST
30    8 AVP(N)=(REFEXR+1.)*DIST
32    M=NTP-1
33    DO 9 N=NFP,M
34    ALP(N)=ALP(NFP-1)+FRAC
35    9 AVP(N)=AVP(NFP-1)-(1.-FRAC)
37    AVP(NTP)=AVP(NFP-1)-(1.-FRAC)
40    ALP(NTP)=BOT
41    AVX=AVP(NFP)
42    AVP(NFP)=AVX+1.-FRAC
C
C     STORAGE OF V AND T PROFILES TO CHCK WITH NEWLY CALCULATED ONES
C
43    DO 469 N=1,NTP
44    469 AVP1(N)=AVP(N)
46    DO 415 N=1,NTP
47    415 TT(N)=T(N)
51    WRITE(6,17) SHFI
C

```


ISN

SOURCE STATEMENT

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C      CALCULATION OF MOLAR LIQUID COMP FLOW RATE/TOP PRODUCT COMP FLOW
C      RATE RATIOS FOR THE ABSORPTION SECT AND MOLAR LIQUID COMP FLOW
C      RATE/BOTTOMS MOLAR COMP FLOW RATE RATIOS FOR THE STRIPPING SECT
C
52      DO 501 N=1,NTP
53      TX=T(N)+459.6
54      CALL KIVAL (N, TX, 3)
55      DO 501 I=1,NCP
56      501 AK(N, I)=VAP(I)
61      GO TO (60, 61), JXX
62      61 TX=TD+459.6
63      CALL KIVAL (NTP+1, TX, 3)
64      DO 62 I=1,NCP
65      62 DLOR(I)=1./VAP(I)
67      GO TO 60
70      50 CONTINUE
71      DO 200 N=1,NTP
72      TX=T(N)+459.6
73      CALL KVAL (TX, N)
74      DO 200 I=1,NCP
75      AK(N, I)=VAP(I)
76      200 CONTINUE
101      60 GO TO (104, 105), JXX
102      104 DO 107 I=1,NCP
103      107 ALIQ(I)=REFXR
105      GO TO 66
106      105 DO 108 I=1,NCP
107      108 ALIQ(I)=REFXR*DLOR(I)
111      66 CALL CFLOWR (ALIQ)
C
C      FEED PLATE MISMATCH INCORPORATING THETA METHOD OF CONVERGENCE
C      SETS THE CORRECTION FOR THE NEW ITERATION
C
112      SUMDI=0.
113      DO 109 I=1,NCP
114      ALQI=ALIQ(NFP, I)*(AK(NFP, I)*AVX/ALP(NFP))+1.0
115      GO TO (121, 122, 123, 123), JX
116      121 C1=1.
117      C2=0.
120      GO TO 120
121      122 C1=0.
122      C2=1.0
123      GO TO 120
124      123 C1=FRAC*XFI(I)/FX(I)
125      C2=(1.-FRAC)*YFI(I)/FX(I)
126      120 BIDI(I)=(ALIQ(NFP-1, I)+C1)/(ALQI-1.+C2)
127      DI(I)=FX(I)/(1.0+BIDI(I))
130      109 SUMDI=SUMDI+DI(I)
132      DEL1=(DIST-SUMDI)
133      WRITE(6, 17) DEL1
C      CONVERGENCE CRITERION
134      IF(KXN.LE.2) GO TO 15
137      IF(ABS(DEL1).LE.1.0E-04.AND.ABS(1.-THET1).LE.1.0E-03) GO TO 400
142      15 CONTINUE
C      THETA CONVERGENCE

```



```

143      CALL THETA (THET1,FX,BIDI)
144      41  FORMAT(1X,6X,18HTHETA CONVERGENCE=,F8.5)
145      WRITE(6,41) THET1
146      SUMDI=0.
147      SUMBI=0.
150      DO 113 I=1,NCP
151      DI(I)=FX(I)/(1.+THET1*BIDI(I))
152      BI(I)=THET1*BIDI(I)*DI(I)
153      SUMDI=SUMDI+DI(I)
154      113 SUMBI=SUMBI+BI(I)
156      DO 712 I=1,NCP
157      DXI(I)=DI(I)/SUMDI
160      XX(I)=DXI(I)
161      712 BXI(I)=BI(I)/SUMBI
C
C      CALCULATING NORMALIZED PLATE COMPOSITIONS
C
163      CALL COMP (DI,BI)
C
C      CALCULATION OF CONDENSER CONDITION
C
164      TD=TD+459.6
165      T(1)=T(1)+459.6
166      CALL DISTIL (TD,XX,SHDI,HDX,NTP+1,YD,XD,REFXR,HDX,HDX,T(1))
167      T(1)=T(1)-459.6
170      TD=TD-459.6
171      DO 42 I=1,NCP
172      42 DLOR(I)=XD(I)/YD(I)
174      WRITE(6,17) HDV
175      WRITE(6,17) SHDI
176      WRITE (6,17) TD
C
C      BUBBLE POINT CALCULATION TO CORRECT TEMPERATURE PROFILE
C
177      DO 309 N=1,NTP
200      TX=T(N)+459.6
201      CALL TEMP (TX,N)
202      309 T(N)=TX-459.6
C
C      CHECK TEMP PROFILE TO DECIDE IF L-V CORRECTIONS ARE TO BE MADE
C
204      KXX=0
205      DO 411 N=1,NTP
206      IF(ABS(TT(N)-T(N)).LE.10.) GO TO 411
211      KXX=1
212      411 CONTINUE
214      DO 412 N=1,NTP
215      T(N)=(T(N)+TT(N))/2.0
216      412 TT(N)=T(N)
220      IF(KXX.EQ.1) GO TO 50
C
C      ENTHALPY BALANCES ARE USED TO CALCULATE NEW VAPOUR-LIQ PROFILES
C      CONDENSER AND REBOILER HEAT LOADS ARE CALCULATED
C
223      DO 117 N=1,NTP

```


| ISN | SOURCE STATEMENT |
|-----|---|
| 224 | TX=T(N)+459.6 |
| 225 | DO 900 I=1,NCP |
| 226 | 900 XX(I)=X(N,I) |
| 230 | CALL HVAL (TX ,YY,XX,2,N) |
| 231 | SHL(N)=HLIQ |
| 232 | DO 901 I=1,NCP |
| 233 | 901 YY(I)=Y(N,I) |
| 235 | CALL HVAL (TX ,YY,XX,1,N) |
| 236 | SHV(N)=HVAP |
| 237 | 117 CONTINUE |
| 241 | DO 915 I=1,NCP |
| 242 | 915 YY(I)=Y(NFP,I) |
| 244 | CALL HVAL (T(NFP)+459.6,YY ,XX,1,NFP) |
| 245 | HHH=HVAP |
| 246 | WRITE(6,17) HHH |
| 247 | SHV(NFP)=((1.-FRAC)*HHX+HHH*AVX)/(1.-FRAC+AVX) |
| 250 | DQC=(HDV-SHDI)*DIST*(REFXR+1.) |
| 251 | GO TO (30,31),JXX |
| 252 | 30 DXD=SHDI |
| 253 | GO TO 32 |
| 254 | 31 DXD=HDY |
| 255 | 32 DQR=DXD*DIST+SHL(NTP)*(1.-DIST)-SHFI+DQC |
| 256 | WRITE(6,17) DQC |
| 257 | WRITE(6,17) DQR |
| 260 | CALL VPLOP(DQC,DQR,SHDI,SHFI,AVP1,HDX,HDY) |
| 261 | AVX=AVP(NFP)-1.0+FRAC |
| 262 | WRITE(6,14) |
| 263 | 14 FORMAT(1X,20X,23HNEW TEMPERATURE PROFILE) |
| 264 | WRITE(6,6) (T(N),N=1,NTP) |
| 271 | WRITE(6,16) |
| 272 | 16 FORMAT(1X,20X,18HNEW VAPOUR PROFILE) |
| 273 | WRITE(6,6) (AVP(N),N=1,NTP) |
| 300 | 351 FORMAT (1X,16H*** ERROR 07 *** ,71HSPECIFICATIONS FOR D AND THETA N
1UT MET WITHIN 25 TRIALS OF L-V PROFILES) |
| 301 | IF(KXN.LE.25) GO TO 350 |
| 304 | WRITE(6,351) |
| 305 | GO TO 400 |
| 306 | 350 CONTINUE |
| 307 | KXN=KXN+1 |
| 310 | GO TO 50 |
| 311 | 400 CONTINUE |
| 312 | AVP(NFP)=AVP(NFP)-1.+FRAC |
| 313 | RETURN |
| 314 | END |

FORTRAN SOURCE LIST

ISN SOURCE STATEMENT

```
0 $IBFTC GOLDIT  NODECK
1 SUBROUTINE GOLDIT (I,Z1,Z2,Z,FZ,ZA,ZB,FZ1,FZ2)
C DETERMINATION OF TRIAL VALUES OF Z FOR GOLDEN SECTION ITERATION
2 REAL Z,Z1,Z2,ZA,ZB,D,FZ,FZ1,FZ2
3 INTEGER I
4 DOUBLE PRECISION TAU
5 TAU = 1.618033989
6 IF (I.EQ.3) GO TO 304
11 IF (I.EQ.2) GO TO 305
14 IF (I.EQ.1) GO TO 302
17 I = 1
20 301 D =ABS((Z1-Z2)/(TAU**2))
21 ZA =Z1+D
22 Z =ZA
23 RETURN
24 302 I =2
25 FZ1 =FZ
26 303 D =ABS((Z1-Z2)/(TAU**2))
27 ZB =Z2-D
30 Z =ZB
31 RETURN
32 304 FZ1 =FZ
33 GO TO 306
34 305 FZ2 =FZ
35 306 IF (FZ1.NE.FZ2) GO TO 307
40 I =1
41 Z1 =ZA
42 Z2 =ZB
43 GO TO 301
44 307 IF (FZ1.LT.FZ2) GO TO 308
47 I =2
50 Z1 =ZA
51 ZA =ZB
52 FZ1 =FZ2
53 GO TO 303
54 308 I =3
55 Z2 =ZB
56 ZB =ZA
57 FZ2 =FZ1
60 GO TO 301
61 END
```

1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 26

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FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

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0 $IBFTC HVAL      NODECK
1      SUBROUTINE HVAL (T,YY,XX,LZ,N)
C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C***** CHAO-SEADER H-VALUES ARE CALCULATED
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
      LAACB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      DIMENSION HIDL(20),YY(20),XX(20),HL(20),HAC(20),HFC(20)
6      Q=T-459.6
7      DO 1 I=1,NCP
10      1 HIDL(I)=AA(1,I)+AA(2,I)*Q+AA(3,I)*Q**2+AA(4,I)*Q**3
12      IF(LZ.EQ.2) GO TO 2
15      SUMHV=0.
16      SUMY=0.
17      DO 3 I=1,NCP
20      SUMY=SUMY+YY(I)
21      3 SUMHV=SUMHV+YY(I)*HIDL(I)
23      H=BBMIX(N)*P/ZZ(N)
24      HVC=(1.5*AAOB(N)*ALOG(1.0+H)+1.0-ZZ(N))*1.987*T*SUMP
25      HVAP=SUMHV-HVC
26      GO TO 7
27      2 SUMHL=0.
30      DO 4 I=1,NCP
31      J=1
32      IF(I.EQ.JA1) GO TO 12
35      IF(I.EQ.JA2) GO TO 11
40      IF(I.EQ.JA3) GO TO 13
43      IF(I.EQ.JA4) GO TO 11
46      IF(I.EQ.JA5) GO TO 11
51      IF(I.EQ.JA6) GO TO 14
54      IF(I.EQ.JA7) GO TO 15
57      GO TO 16
60      11 J=2
61      GO TO 16
62      12 J=3
63      GO TO 16
64      13 J=4
65      GO TO 16
66      14 J=5
67      GO TO 16
70      15 J=6
71      16 CONTINUE
72      TR=T/CT(I)
73      PR=P/PC(I)
74      CON1=-A(2,J)/TR**2+A(3,J)+2.0*A(4,J)*TR+3.0*A(5,J)*TR**2+(A(7,J)+2
      1.0*A(8,J)*TR)*PR+A(10,J)*PR**2+(A(12,J)-A(13,J)/TR**2+3.0*A(14,J)*
      2TR**2)*W(I)
75      CON1=CON1*2.30259/CT(I)
76      HFC(I)=CON1
77      HAC(I)=-((V1(I)*(DELTA(I)-DDELMX(N))**2)/(1.987*(T**2)))*1.8
100     HL(I)=- (HFC(I)+HAC(I))*1.987*T**2+HIDL(I)
101     4 SUMHL=SUMHL+XX(I)*HL(I)
103     HLIQ=SUMHL
104     7 CONTINUE

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| ISN | SOURCE STATEMENT |
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| | |
|-----|--------|
| 105 | RETURN |
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|-----|-----|
| 106 | END |
|-----|-----|

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

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0 $IBFTC INTERP  NODECK
1     SUBROUTINE INTERP (MX1,MX2,X,Y,Z,X1,Y1,SMS)
C     LINEAR INTERPOLATION SUBROUTINE FOR L/V-MIN,L/V-OPPERATING AND SM/S
2     DIMENSION X(25),Y(25,25),Z(25,25)
3     DO 21 I=1,MX1
4     IF(X(I).GT.X1) GO TO 22
7     IF(MX1.EQ.I) GO TO 31
12    GO TO 21
13    31 WRITE(6,2)
14    SMS=1.
15    RETURN
16    2 FORMAT (1X,10X,10H*****ERROR,10X,22HMIN (L/V)  GREATER 1.0)
17    22 DEL=X1-X(I-1)
20    D=X(I)-X(I-1)
21    K=I-1
22    GO TO 23
23    21 CONTINUE
25    23 DO 35 J=1,MX2
26    IF( Y(K,J).GT. Y1) GO TO 25
31    IF(J.EQ.MX2) GO TO 24
34    GO TO 35
35    24 WRITE(6,3)
36    SMS=1.
37    RETURN
40    3 FORMAT(1X,10X,10H*****ERROR,10X,29HOPERATING (L/V) GREATER 1.0 )
41    25 S11=( Y(K+1,J)*DEL+(D-DEL)* Y(K,J))/D
42    S12=( Y(K+1,J-1)*DEL+(D-DEL)* Y(K,J-1))/D
43    Z11=(Z(K+1,J)*DEL+(D-DEL)*Z (K,J))/D
44    Z12=(Z(K+1,J-1)*DEL+(D-DEL)*Z(K,J-1))/D
45    DEL1=Y1-S12
46    D1=S11-S12
47    GO TO 28
50    35 CONTINUE
52    28 SMS=(DEL1*Z11+(D1-DEL1)*Z12)/D1
53    RETURN
54    END

```


ISN

SOURCE STATEMENT

```

0 $IBFTC INITRP  NODECK
1      SUBROUTINE INITRP (XL,YL,X,Y,Z,X1,Y1,YF)
C***  LAGRANGIAN INTERPOLATION SUBROUTINE
2      INTEGER XL,YL
3      DIMENSION X(25),Y(25,25),Z(25,25),YT(25)
4      7 FORMAT(1X,E15.8)
5      DO 10 I=1,XL
6      L=I
7      10 IF(X1.LT.X(I)) GO TO 11
13     X1=X(L)
14     11 L1=L-4
15     L2=L-1
16     IF(L1.GT.0) GO TO 12
21     IF(L1.GT.(-1)) GO TO 13
24     CALL INTERP (XL,YL,X,Y,Z,X1,Y1,YF)
25     RETURN
26     13 L1=1
27     12 DO 50 L=L1,L2
30     DO 14 I=1,YL
31     K=I
32     14 IF(Y1.LT.Y(L,I)) GO TO 15
36     YF=1.0
37     RETURN
40     15 K1=K-2
41     K2=K+1
42     IF(K1.EQ.0) K1=1
45     IF(K2.LE.YL) GO TO 16
50     K2=YL
51     K1=YL-3
52     16 YT(L)=0.0
53     DO 50 IK=K1,K2
54     YP=1.00
55     DO 17 JK=K1,K2
56     IF (JK.EQ.IK) GO TO 17
61     XZ=(Y1-Y(L,JK))/(Y(L,IK)-Y(L,JK))
62     YP=YP*XZ
63     17 CONTINUE
65     50 YT(L)=YT(L)+YP*Z(L,IK)
70     YF=0.00
71     DO 18 IL=L1,L2
72     YP=1.00
73     DO 19 JL=L1,L2
74     IF (JL.EQ.IL) GO TO 19
77     XR=(X1-X(JL))/(X(IL)-X(JL))
100    YP=YP*XR
101    WRITE(6,7) YT(IL)
102    19 CONTINUE
104    WRITE(6,7) YP
105    18 YF=YF+YP*YT(IL)
107    WRITE(6,7) YF
110    RETURN
111    END

```


15N SOURCE STATEMENT

```

0 $IBFTC IN2PUT NUDECK
1 SUBROUTINE IN2PUT (MX1,MX2,B,C,D)
C INPUT DATA FOR INTERPOLATION SUBROUTINE
2 DIMENSION B(25),C(25,25),D(25,25)
3 1 FORMAT(1X,11F6.4)
4 MX1=22
5 MX2=22
6 READ(5,1)(B(I),I=1,MX1)
13 MX1=21
14 READ(5,1)(( C(I,J),J=1,MX2),I=1,MX1)
25 READ(5,1)((D(I,J),J=1,MX2),I=1,MX1)
36 MX2=21
37 RETURN
40 END

```


FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```

0  $IBFIC KVAL      NODECK
1      SUBROUTINE KVAL (TX,N)
C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C***** CHAO-SEADER K-RATIOS
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
      LAADB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      DIMENSION FNU(20),ARK(20),BRK(20),PHI(20),GAM(20),VAPL(20)
6      200 FORMAT (1X,16H*** ERROR 02 *** ,55H MORE THAN THIRTY TRIALS ARE REQ
      1IRED FOR Z CONVERGENCE )
7      DO 101 I=1,NCP
10      J=1
11      IF(I.EQ.JA1) GO TO 12
14      IF(I.EQ.JA2) GO TO 11
17      IF(I.EQ.JA3) GO TO 13
22      IF(I.EQ.JA4) GO TO 11
25      IF(I.EQ.JA5) GO TO 11
30      IF(I.EQ.JA6) GO TO 14
33      IF(I.EQ.JA7) GO TO 15
36      GO TO 16
37      11 J=2
40      GO TO 16
41      12 J=3
42      GO TO 16
43      13 J=4
44      GO TO 16
45      14 J=5
46      GO TO 16
47      15 J=6
50      16 CONTINUE
51      TR=TX/CT(I)
52      PR=P/PC(I)
53      FPO=A(1,J)+A(2,J)/TR+A(3,J)*TR+A(4,J)*TR**2+A(5,J)*TR**3+(A(5,J)+A
      1(7,J)*TR+A(8,J)*TR**2)*PR+(A(9,J)+A(10,J)*TR)*PR**2-ALOG(PR)/2.303
54      FPI=(A(11,J)+A(12,J)*TR+A(13,J)/TR+A(14,J)*TR**3+A(15,J)*(PR-0.6))
55      101 FNU(I)=(FPO+W(I)*FPI)*2.303
57      AMIX=0.0
60      BMIX=0.0
61      DO 102 I=1,NCP
62      TR=TX/CT(I)
63      ARK(I)=(0.4278/(PC(I)*TR**2.5))**0.5
64      BRK(I)=0.0867/(PC(I)*TR)
65      BMIX=BMIX+BRK(I)*Y(N,I)
66      102 AMIX=AMIX+ARK(I)*Y(N,I)
70      AUB=AMIX*AMIX/BMIX
71      CON1=2.0
72      CON2=BMIX*P+0.001
73      DO 106 K=1,30
74      ZAS=(CON1+CON2)/2.0
75      H=BMIX*P/ZAS
76      Z=1.0/(1.0-H)-A0B*(H/(1.0+H))
77      DEL=Z-ZAS
100      IF(ABS(DEL).LE.1.0E-04) GO TO 107
103      IF(DEL.LT.0.0) GO TO 104

```


| ISN | SOURCE STATEMENT |
|-----|--|
| 106 | IF(DEL.GT.0.) GO TO 105 |
| 111 | 104 CON1=ZAS |
| 112 | GO TO 106 |
| 113 | 105 CON2=ZAS |
| 114 | 106 CONTINUE |
| 116 | WRITE(6,200) |
| 117 | 107 DO 108 I=1,NCP |
| 120 | 108 PHI(I)=(Z-1.0)*(BRK(I)/BMIX)-ALOG(Z-BMIX*P)-AOB*((2.0*ARK(I))/AMIX
1-(BRK(I)/BMIX))*ALOG(1.0+H) |
| 122 | CON1=0.0 |
| 123 | CON2=0.0 |
| 124 | DO 109 I=1,NCP |
| 125 | DELMX=X(N,I)*V1(I) |
| 126 | CON1=CON1+DELMX |
| 127 | 109 CON2=CON2+DELMX*DELTA(I) |
| 131 | DELMX=CON2/CON1 |
| 132 | CON1=1.987*TX/1.8 |
| 133 | DO 110 I=1,NCP |
| 134 | GAM(I)=V1(I)*(DELTA(I)-DELMX)**2/CON1 |
| 135 | VAPL(I)=(FNU(I)+GAM(I)-PHI(I)) |
| 136 | 110 VAP(I)=EXP(VAPL(I)) |
| 140 | AAOB(N)=AOB |
| 141 | BBMIX(N)=BMIX |
| 142 | ZZ(N)=Z |
| 143 | DDELMX(N)=DELMX |
| 144 | RETURN |
| 145 | END |

11

100

[illegible]
$$C = C_{\text{eff}} + \frac{1}{2} \Delta C_{\text{eff}} \quad (10)$$

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```

0 $IBFTC KIVAL  NNODECK
1  SUBROUTINE KIVAL (N,TX,LL)
C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C*****  IDEAL K-RATIOS AS A FUNCTION OF TR AND PR ONLY
2  COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
  1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3  COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4  COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5  DIMENSION FN1(20),AKK(20)
6  DO 1 I=1,NCP
7  J=1
10  IF(I.EQ.JA1) GO TO 12
13  IF(I.EQ.JA2) GO TO 11
16  IF(I.EQ.JA3) GO TO 13
21  IF(I.EQ.JA4) GO TO 11
24  IF(I.EQ.JA5) GO TO 11
27  IF(I.EQ.JA6) GO TO 14
32  IF(I.EQ.JA7) GO TO 15
35  GO TO 16
36  11 J=2
37  GO TO 16
40  12 J=3
41  GO TO 16
42  13 J=4
43  GO TO 16
44  14 J=5
45  GO TO 16
46  15 J=6
47  16 CONTINUE
50  TR=TX/CT(I)
51  PR=P/PC(I)
52  FP1=A(1,J)+A(2,J)/TR+A(3,J)*TR+A(4,J)*TR**2+A(5,J)*TR**3+(A(6,J)+A
  1(7,J)*TR+A(8,J)*TR**2)*PR+(A(9,J)+A(10,J)*TR)*PR**2-ALOG(PR)/2.303
53  FP2=(A(11,J)+A(12,J)*TR+A(13,J)/TR+A(14,J)*TR**3+A(15,J)*(PR-0.6))
54  FN1(I)=(FP1+W(I)*FP2)*2.303
55  1 AKK(I)=EXP(FN1(I))
57  DO 99 I=1,NCP
60  99 VAP(I)=AKK(I)
62  IF(LL.EQ.3) GO TO 5
65  IF(LL.EQ.2) GO TO 3
70  DO 2 I=1,NCP
71  2 X(N,I)=Y(N,I)/AKK(I)
73  GO TO 5
74  3 DO 4 I=1,NCP
75  4 Y(N,I)=X(N,I)*AKK(I)
77  5 CONTINUE
100  RETURN
101  END

```


ISN SOURCE STATEMENT

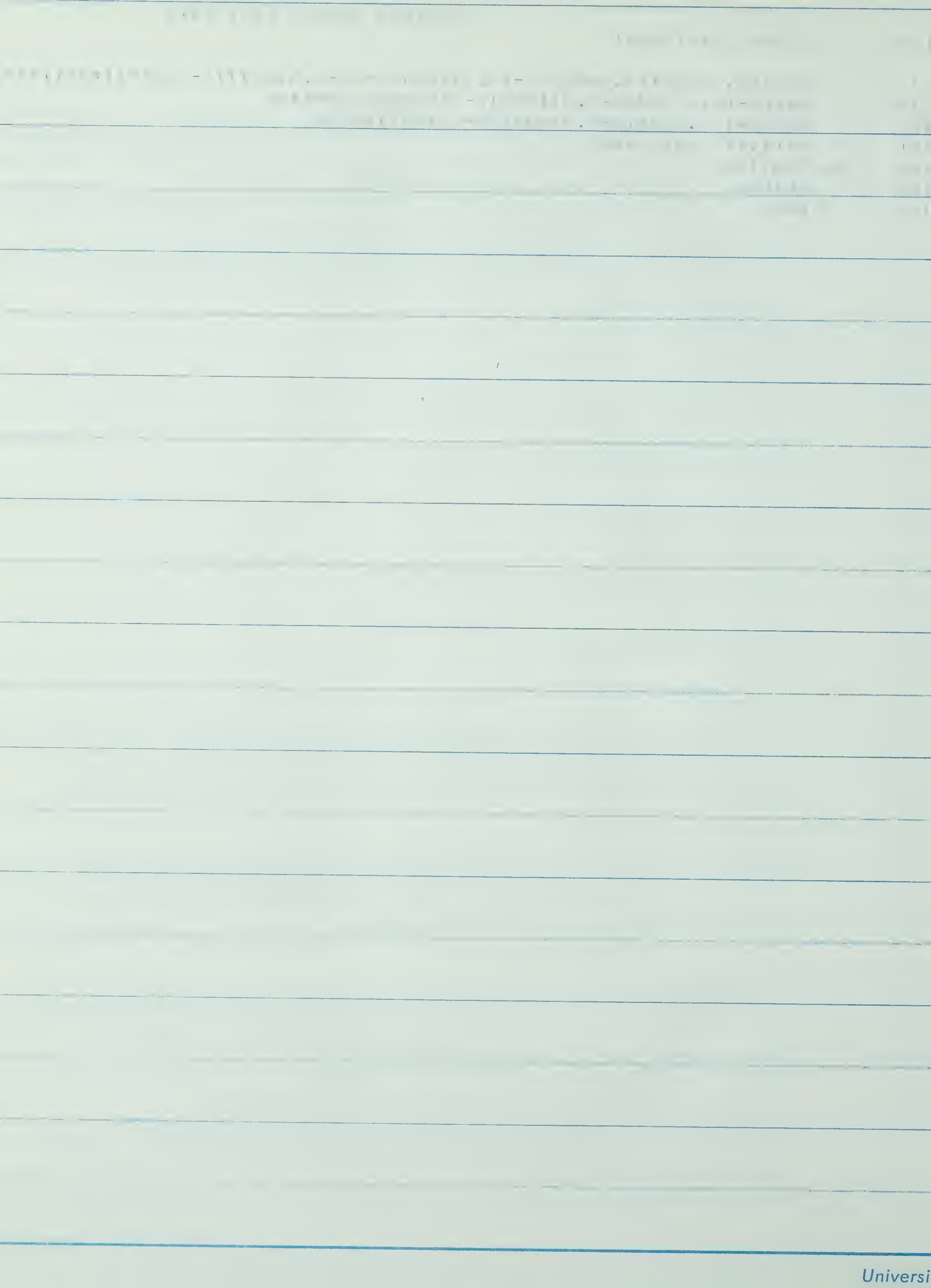
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0 $IBFTC PHYS      NODECK
1 SUBROUTINE PHYS (NC,XMT)
C ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C*** PHYSICAL PROPERTIES ARE CALCULATED FOR HYPOTHETICAL COMPONENTS
C***** TO CALCULATE CHAO-SEADER K-RATIOS AND H-VALUES *****
C***** ----- CAVETTES METHOD -----
2 COMMON/ONE/ CT(20),PC(20),w(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELTX(51),HLIQ,HVAP
3 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4 COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5 COMMON/FIVE/ REFRR, BXI(20),DXI(20),TD,TW,TF,FX(20)
6 DIMENSION XMT(20,2)
7 33 FORMAT(1X, E14.7)
10 50 FORMAT(1X,7F8.3,11X,2A6)
11 M=NC+1
12 DO 20 I=M,NCP
13 READ(5,50)BPCA,BMLA,BPMNA,TC1,PC1,API,XXWM,(XMT(I,J),J=1,2)
20 READ (5,33) FX(I)
21 SPG=141.5/(API+131.5)
22 IF(BPMNA.EQ.0.) GO TO 1
25 GO TO 2
26 1 BPMNA=(BPCA+BMLA)/2.0
27 2 XRHO=0.98907*SPG
30 V1(I)=XXWM/XRHO
31 UOPK=((BPMNA+459.6)**(1.0/3.0))/SPG
32 IF(TC1.EQ.0.) GO TO 3
35 GO TO 4
36 3 IF(BMLA.EQ.0.) GO TO 9
41 BP=BMLA
42 GO TO 11
43 9 BP=BPMNA
44 11 CONTINUE
45 TC1=768.07121+(1.7133693-0.10834003E-02*BP )*BP
46 TC1=TC1-0.89212579E-02*API*BP +0.38890584E-06*BP **3
47 TC1=TC1+((0.53094920E-05+0.32711600E-07*API)*API)*BP **2
50 4 CT(I)=TC1
51 IF(PC1.EQ.0.) GO TO 5
54 GO TO 6
55 5 PC1=2.8290406+(0.94120109E-03-0.30474749E-05*BPMNA)*BPMNA
56 PC1=PC1-0.20876110E-04*API*BPMNA+0.15184103E-08*BPMNA**3
57 PC1=PC1+((+.11047899E-07+0.13949619E-09*API)*API)*BPMNA**2
60 PC1=PC1-0.48271599E-07*API**2*BPMNA
61 PC1=EXP (PC1*2.303)
62 6 PC(I)=PC1
63 BP=BPMNA+459.6
64 W(I)=(3.0/7.0)*((ALOG(PC1/14.696))/2.303)/(TC1/BP-1.0)-1.0
65 DEHV= (7.58+4.571*(ALOG(BP ))/2.303)*(BPMNA+459.6)/1.8
66 DEHV=DEHV*((TC1-537.)/(TC1-(BPMNA+459.6)))*0.38
67 DELTA(I) =((DEHV-592.4)/V1(I) ) **0.5
70 AA(3,I) =XXWM*(3.1073165E-04-5.832381E-08*API)
71 AA(4,I) =XXWM*(9.1745019E-11*API-5.6334748E-08)
72 HB=-.81862040+ (-2.8568654E-05+1.7024654E-06*API)*API
73 HB=HB-1.4886832E-08*API**3 -3.0836492E-04*UOPK**3
74 HB=HB+(8.8395563E-02+4.2934703E-03*UOPK)*UOPK
75 AA(2,I) =XXWM*HB

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FORTRAN SOURCE LIST PHYS

| ISN | SOURCE STATEMENT |
|-----|--|
| 76 | HB=188.25000+(3.5442502-(5.2716944E-02-3.5353777E-04*API)*API)*API |
| 77 | HB=HB-(8.9530784-3.5118581E-01*UOPK)*UOPK**2 |
| 100 | HB=HB+(43.401618-5.9563889E-03*API)*UOPK |
| 101 | AA(1,1) =XXWM*HB |
| 102 | 20 CONTINUE |
| 104 | RETURN |
| 105 | END |



FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```

0 $IBFTC PSY      NODECK
C ***** SUBROUTINE USED WITH BERGAMINI PROCEEDURE ONLY *****
C *****SLOPE OF LJO K VS TEMP CALCULATED *****
1      SUBROUTINE PSY (TX,K,N,PSI)
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,3),
      LAAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/ JX,JA,JB,JC,JD,JE,JXX,FRAC,FRC,AA(4,20)
5      DIMENSION CK(20),PSI(51,20)
6      TB=TX+5.0
7      CALL KVAL (TB,N)
10     DO 1 I=1,NCP
11     CK(I)=VAP(I)
12     1 PSI(N,I)=(ALOG10(CK(I))-ALOG10(AK(K,I)))/5.0
14     RETURN
15     END

```

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FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```

0 $IBFTC SINPUT
1 SUBROUTINE SINPUT (NC,NHC,DI,BI,FI,P,RARM ,ILK,IHK,TF,XMT,ITERP)
C SHORTCUT INPUT SUBROUTINE
2 COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3 COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
4 DIMENSION DI(20),BI(20),FI(20)
5 DIMENSION XMT(20,2)
6 2 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
7 3 FORMAT(1X,3E14.7)
10 4 FORMAT(1X,4E14.7)
11 17 FORMAT (1X,2I3)
12 18 FORMAT (1X,4I3,F8.5,2F8.2,I3)
13 19 FORMAT(1X,F8.5,7I3)
14 100 FORMAT(8F10.6)
15 READ (5,18) NC,NHC,JX,JXX,RARM ,TF,P,ITERP
23 READ(5,17) ILK,IHK
26 READ(5,19) FRC,JA1,JA2,JA3,JA4,JA5,JA6,JA7
36 DO 1 I=1,NC
37 READ(5,2) CT(I),PC(I),W(I),DELTA(I),V1(I),(XMT(I,J),J=1,2)
44 READ (5,3) FI(I),DI(I),BI(I)
45 1 READ(5,4)(AA(J,I),J=1,4)
53 READ(5,100)((A(I,J),I=1,16),J=1,6 )
64 RETURN
65 END

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FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

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0  $IBFTC SOUTPT  NODECK
1      SUBROUTINE SOUTPT (DQC,DQR,AN,SZ,XMT,RM)
C      OUTPUT SUBROUTINE FOR SHORTCUT METHOD
2      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3      COMMON/FIVE/ REFXX,      BXI(20),DXI(20),TD,TW,TF,FX(20)
4      DIMENSION XMT(20,2)
5      WRITE(6,3)
6      3 FORMAT (1H2)
7      WRITE(6,1)
10     1 FORMAT (1HS,27X,16HSHORT CUT METHOD)
11     2 FORMAT (1HS,25X,22HBASIS ONE LB-MOLE FEED)
12     WRITE(6,2)
13     WRITE(6,15)RM
14     15 FORMAT(1HS,20X,24HSHORTCUT MINIMUM REFLUX=,F8.4)
15     4 FORMAT(1HS,10X,56HSHORTCUT NUMBER OF THEORETICAL PLATES AT TOTAL
16         1 REFLUX=,F8.4)
16     WRITE(6,4) AN
17     5 FORMAT(1HS,10X,58HSHORTCUT NUMBER OF THEORETICAL PLATES AT OPERATI
18         ING REFLUX=,F8.4)
20     WRITE(6,5) SZ
21     6 FORMAT(1HS,15X,16HDISTILLATE TEMP=,F8.3, 5X,25HNO OF THEORETICAL P
22         LATES=,I4)
22     WRITE(6,6) TD,NTP
23     7 FORMAT(1HS,9X,13HREFLUX RATIO=,F8.5, 2X,16HDISTILLATE RATE=,F8.5,
24         1 2X ,14HFEED PLATE NO=,I3)
24     WRITE(6,14) TW,P
25     14 FORMAT (1HT,15X,13HBOTTOMS TEMP=,F8.3,2H F,5X,16HCOLUMN PRESSURE=,
26         1F8.3,5H PSIA)
26     WRITE(6,7) REFXX,DIST,NFP
27     8 FORMAT (1HT,10X,20HCONDENSER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
28         IED )
30     9 FORMAT (1HT,10X,20HREBOILER HEAT LOAD=,E15.8,2X,19HBTU/LB MOLE FE
31         IED )
31     WRITE(6,8) DQC
32     WRITE(6,9) DQR
33     10 FORMAT(1HS,25X,30HCOMPOSITIONS IN MOLE FRACTIONS)
34     WRITE(6,10)
35     11 FORMAT(1HJ,5X,9HCOMPONENT,5X,10H FEED ,10X,10HDISTILLATE,7X,10
36         1H BOTTOMS )
36     WRITE(6,11)
37     13 FORMAT(1X,4X,246,3X,E15.8, 5X,E15.8, 5X,E15.8)
40     DO 12 I=1,NCP
41     12 WRITE(6,13) (XMT(I,J),J=1,2),FX(I),DXI(I),BXI(I)
47     WRITE(6,3)
50     RETURN
51     END

```

()

100

[illegible]

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

15N SOURCE STATEMENT

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0 4IRFTC SPHYS  NNODECK
1      SUBROUTINE SPHYS (NC,XMT,F1,DI,BI)
C      *** SUBROUTINE USED WITH SHORTCUT METHOD ONLY *****
C***    PHYSICAL PROPERTIES ARE CALCULATED IN THIS SUBROUTINE FOR HYPOTHETICAL
C***    COMPONENTS TO CALCULATE CHAO-SEADER K-RATIOS AND H-VALUES
C*****    ----- CAVETTES METHOD -----
2      COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AADB(51),ZZ(51),BBMIX(51),LDELTX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      COMMON/FIVE/ REFRR,      BXI(20),DXI(20),TD,TW,TF,Fx(20)
6      DIMENSION XMT(20,2)
7      DIMENSION FI(20),DI(20),BI(20)
10     33 FORMAT(1X,3E14.7)
11     50 FORMAT(1X,7F8.3,11X,2A6)
12     M=NC+1
13     DO 20 I=M,NCP
14     READ(5,50)BPCA,BMLA,BPMNA,TC1,PC1,API,XXWM,(XMT(I,J),J=1,2)
21     READ (5,33) FI(I),DI(I),BI(I)
22     SPG=141.5/(API+131.5)
23     IF(BPMNA.EQ.0.) GO TO 1
26     GO TO 2
27     1 BPMNA=(BPCA+BMLA)/2.0
30     2 XRHO=0.98907*SPG
31     V1(I)=XXWM/XRHO
32     UOPK=((BPMNA+459.6)**(1.0/3.0))/SPG
33     IF(TC1.EQ.0.) GO TO 3
36     GO TO 4
37     3 IF(BMLA.EQ.0.) GO TO 9
42     BP=BMLA
43     GO TO 11
44     9 BP=BPMNA
45     11 CONTINUE
46     TC1=768.07121+((1.7133693-0.10834003E-02*BP )*BP
47     TC1=TC1-0.89212579E-02*API*BP +0.38890584E-06*BP **3
50     TC1=TC1+((0.53094920E-05+0.32711600E-07*API)*API)*BP **2
51     4 CT(I)=TC1
52     IF(PC1.EQ.0.) GO TO 5
55     GO TO 6
56     5 PC1=2.8290406+((0.94120109E-03-0.30474749E-05*BPMNA)*BPMNA
57     PC1=PC1-0.20876110E-04*API*BPMNA+0.15184103E-08*BPMNA**3
60     PC1=PC1+((+.11047899E-07+0.13949619E-09*API)*API)*BPMNA**2
61     PC1=PC1-0.48271599E-07*API**2*BPMNA
62     PC1=EXP (PC1*2.303)
63     6 PC(I)=PC1
64     BP=BPMNA+459.6
65     W(I)=(3.0/7.0)*((ALOG(PC1/14.696))/2.303)/(TC1/BP-1.0)-1.0
66     DEHV= (7.58+4.571*(ALOG(BP ))/2.303)*(BPMNA+459.6)/1.8
67     DEHV=DEHV*((TC1-537.)/(TC1-(BPMNA+459.6)))*0.38
70     DELTA(I) =((DEHV-592.4)/V1(I) ) **0.5
71     AA(3,I) =XXWM*(3.1073165E-04-5.832381E-08*API)
72     AA(4,I) =XXWM*(9.1745019E-11*API-5.6334748E-08)
73     HB=-.81862040+ (-2.8568654E-05+1.7024654E-06*API)*API
74     HB=HB-1.4886832E-08*API**3 -3.0836492E-04*UOPK**3
75     HB=HB+(8.8395563E-02+4.2934703E-03*UOPK)*UOPK

```

Handwritten mathematical notes on lined paper, featuring various equations and derivations. The text is written in a cursive script and includes several lines of algebraic manipulation, possibly involving trigonometric or calculus concepts. The page is numbered 1 in the top right corner.

ISN

SOURCE STATEMENT

```
76      AA(2,I) =XXWM*HB
77      HB=188.25000+(3.5442502-(5.2716944E-02-3.5353777E-04*API)*API)*API
100     HB=HB-(8.9530784-3.5118581E-01*UOPK)*UOPK**2
101     HB=HB+(43.401618-5.9563889E-03*API)*UOPK
102     AA(1,I) =XXWM*HB
103 20  CONTINUE
105     RETURN
106     END
```

Table 1: Summary of the data

| Year | Country | Population (millions) | GDP (billions of USD) | Life expectancy (years) |
|------|---------|-----------------------|-----------------------|-------------------------|
| 2011 | USA | 311 | 15.7 | 78.4 |
| 2012 | USA | 313 | 16.1 | 78.6 |
| 2013 | USA | 315 | 16.5 | 78.8 |
| 2014 | USA | 317 | 16.9 | 79.0 |
| 2015 | USA | 319 | 17.3 | 79.2 |
| 2016 | USA | 321 | 17.7 | 79.4 |
| 2017 | USA | 323 | 18.1 | 79.6 |
| 2018 | USA | 325 | 18.5 | 79.8 |
| 2019 | USA | 327 | 18.9 | 80.0 |
| 2020 | USA | 329 | 19.3 | 80.2 |

ISN

SOURCE STATEMENT

```

0 $IBFTC SRTCUT NODCK
1 SUBROUTINE SRTCUT (DI,BI,XFI,YFI,SHFI,ILK,IHK,HXX,KARM,AN,SZ,DQC,
  IDQR,ITERP,RM)
C ***** FENSKE-UNDERWOOD-MADDOX SHORTCUT METHOD *****
2 COMMON/ONE/ CT(20),PC(20),W(20),DELTA(20),VI(20),VAP(20),A(16,6),
  IAAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3 COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4 COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5 COMMON/FOUR/ AVP(50),ALP(50),T(50)
6 COMMON/FIVE/ REFEX, BXI(20),DXI(20),TD,TW,TF,FX(20)
7 COMMON/SIX/ SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
10 DIMENSION DI(20),BI(20),XFI(20),YFI(20),FK(20),DK(20),BK(20),ALPHA
  I(20),DIBI(20)
11 DIMENSION B(25),C(25,25),D(25,25)
12 DIMENSION XD(20),YD(20)
13 DIMENSION XX(20),YY(20)
14 REAL LVM,LVD
15 500 FORMAT(1X,10X,E14.7)
16 501 FORMAT(1X,10X,5E14.7)
17 CALL IN2PUT (MX1,MX2,B,C,D)
20 DO 8 I=1,NCP
21 8 FK(I)=VAP(I)
23 CALL HVAL(TF,YY,FX,2,NTP+2)
24 HZ=HLIQ
25 CALL HVAL (TF,FX,XX,1,NTP+2)
26 HY=HVAP
27 HXX=HY
30 Q=(HY-SHFI)/(HY-HZ)
31 WRITE(6,500) Q
C
C USING FENSKE EQUATION TO CALCULATE MINIMUM NUMBER OF THEORETICAL
C PLATES AT TOTAL REFLUX
C
32 CDX=0.
33 BBX=0.
34 DO 4 I=1,NCP
35 DDX=DDX+DI(I)
36 4 BRX=BRX+BI(I)
40 DO 5 I=1,NCP
41 DXI(I)=DI(I)/DDX
42 5 BXI(I)=BI(I)/BBX
44 TD=TF+30.
45 TB=TF-30.
46 21 CONTINUE
47 GO TO (10,11),JXX
50 10 CALL BUBPT (DXI,TD,NTP+1)
51 DO 9 I=1,NCP
52 9 DK(I)=VAP(I)
54 GO TO 12
55 11 CALL DEWPT(DXI,TB,NTP+1)
56 DO 7 I=1,NCP
57 7 DK(I)=VAP(I)
61 12 CONTINUE
62 CALL BUBPT (BXI,TB,NTP)
63 DO 6 I=1,NCP

```


ISN SOURCE STATEMENT

```

64      6 BK(I)=VAP(I)
66      CALL HVAL (TB,YY,BXI,2,NTP)
67      SHBI=HLIQ
70      DO 13 I=1,NCP
71      13 ALPHA(I)=(DK(I)/DK(IHK)*FK(I)/FK(IHK)*BK(I)/BK(IHK))**0.333333
73      GO TO (14,15),JXX
74      14 AN=ALOG(DXI(ILK)/DXI(IHK)*BXI(IHK)/BXI(ILK))/ALOG(ALPHA(ILK))
75      GO TO 16
76      15 AN=ALOG(DXI(ILK)/DXI(IHK)*BXI(IHK)/BXI(ILK))/ALOG(ALPHA(ILK))-1.0
77      16 DO 17 I=1,NCP
100      IF(I.EQ.ILK.OR.I.EQ.IHK) GO TO 17
103      DIBI(I)=ALPHA(I)**AN*DI(IHK)/BI(IHK)
104      DI(I)=(DI(IHK)/BI(IHK)*ALPHA(I)**AN*FX(I))/(1.+DI(IHK)/BI(IHK)*ALP
105      IHA(I)**AN)
107      17 CONTINUE
107      WRITE(6,500) AN
110      DIST=0.
111      DO 18 I=1,NCP
112      IF(I.EQ.ILK.OR.I.EQ.IHK) GO TO 18
115      BI(I)=DI(I)/DIBI(I)
116      18 DIST=DIST+DI(I)
120      CK=0.
121      DO 19 I=1,NCP
122      CX=DI(I)/DIST
123      IF(ABS(CX-DXI(I)).LE.1.0E-04) GO TO 20
126      CK=1.
127      20 DXI(I)=CX
130      19 BXI(I)=BI(I)/(1.-DIST)
132      IF(CK.LE.0.) GO TO 22
135      GO TO 21
136      22 BOT=1.-DIST
137      WRITE(6,501) (ALPHA(I),I=1,NCP)
144      WRITE(6,500) TD
145      WRITE(6,500) TB
C
C      MINIMUM REFLUX IS CALCULATED BY THE UNDERWOOD METHOD
C      THE GOLDEN SECTION SEARCH IS USED TO SOLVE THE UNDERWOOD EQN'S
C
146      I=0
147      Z1=ALPHA(IHK)
150      Z2=ALPHA(ILK)
151      32 CONTINUE
152      CALL GOLDIT (I,Z1,Z2,Z,FZ,ZA,ZB,FZ1,FZ2)
153      FZ=0.
154      DO 23 J=1,NCP
155      23 FZ=FZ+(ALPHA(J)*FX(J))/(ALPHA(J)-Z)
157      FZ=ABS(FZ+1.-Q)
160      IF(FZ.LE.1.0E-05) GO TO 24
163      GO TO 32
164      24 S=0.
165      WRITE(6,500) Z
166      WRITE(6,500) FZ
167      DO 25 I=1,NCP
170      25 S=S+ALPHA(I)*DXI(I)/(ALPHA(I)-Z)
172      RMR=S-1.

```


ISN SOURCE STATEMENT

```

173 WRITE(6,500) RMR
174 S=0.
175 DO 26 I=1,NCP
176 26 S=S+ ALPHA(I)*BXI(I)/(ALPHA(I)-Z)
200 RMB=(-S*BOT+(1.-FRAC)-DIST)/DIST
201 WRITE(6,500) RMB
202 RM=RMR-RMB
203 IF(RM.GE.0.) GO TO 27
206 RM=RMB
207 GO TO 28
210 27 RM=RMR
211 28 CONTINUE
212 WRITE(6,500) RM
213 REFXR=RM*RARM
214 JFF=0
215 71 CONTINUE

```

C
C
C

SHORTCUT REBOILER AND CONDENSER HEAT LOADS ARE CALCULATED

```

216 GO TO (40,41),JXX
217 41 DFRAC=REFXR/(REFXR+1.)
220 DO 49 I=1,NCP
221 YD(I)=DXI(I)
222 XD(I)=DXI(I)/DK(I)
223 49 Y(1,I)=DFRAC*XD(I)+(1.-DFRAC)*YD(I)
225 GO TO 42
226 40 DO 48 I=1,NCP
227 48 Y(1,I)=DXI(I)
231 42 T(1)=TD
232 DO 44 I=1,NCP
233 44 YY(I)=Y(1,I)
235 CALL DEWPT (YY,T(1),1)
236 WRITE(6,500) T(1)
237 DO 43 I=1,NCP
240 43 XX(I)=DXI(I)
242 CALL DISTIL (TD,XX,SHDI,HDV,NTP+1,YD,XD,REFXR,HDX,H DY,T(1))
243 WRITE(6,500) SHDI
244 WRITE(6,500) HDV
245 DQC=(HDV-SHDI)*DIST*(REFXR+1.)
246 GO TO (55,52),JXX
247 55 DXD=SHDI
250 GO TO 53
251 52 DXD=HDY
252 53 DQR= DXD *DIST+SHBI*(1.-DIST)-SHFI+DQC
253 WRITE(6,500) DQR
254 WRITE(6,500) DQC
255 VK=REFXR*DIST+DIST
256 WRITE (6,500) VK
257 IF(JFF.EQ.1) GO TO 33
262 LVM=(RM*DIST)/(RM*DIST+DIST)
263 LVO=(VK-DIST)/VK
264 WRITE(6,500) LVM
265 WRITE(6,500) LVO

```

C
C

LINEAR OR LAGRANGIAN INTERPOLATION IS MADE OF THE MADDOX CHARTS

| ISN | SOURCE STATEMENT |
|-----|--|
| | C TO OBTAIN OPPERATING REFLUX AND THE NUMBER OF IDEAL STAGES |
| | C |
| 266 | GO TO (75,76),ITERP |
| 267 | 75 CALL INTERP (MX1,MX2,B,C,D,LVM,LVO,SMS) |
| 270 | GO TO 77 |
| 271 | 76 CALL INITRP (MX1,MX2,B,C,D,LVM,LVO,SMS) |
| 272 | 77 SZ=AN/SMS |
| 273 | WRITE(6,500) SMS |
| 274 | WRITE(6,500) SZ |
| 275 | SI=1. |
| 276 | 35 DEL=SI-SZ |
| 277 | IF(DEL.GE.0.0) GO TO 37 |
| 302 | SI=SI+1. |
| 303 | GO TO 35 |
| 304 | 37 DEL=(TB-TD)/SI |
| 305 | NTP=SI |
| 306 | ANFP=(TF-TD)/DEL |
| 307 | NFP=ANFP |
| 310 | GO TO (33,34,34,34),JX |
| 311 | 34 CONTINUE |
| 312 | GO TO (50,51),JXX |
| 313 | 50 ALL=VK |
| 314 | GO TO 36 |
| 315 | 51 ALL=VK-DIST |
| 316 | 36 VK =VK +(1.-DIST)*(SHFI-HZ)/(DQC/ALL) |
| 317 | REFXR=(VK-DIST)/DIST |
| 320 | JFF=1 |
| 321 | GO TO 71 |
| 322 | 33 CONTINUE |
| 323 | TW=TB |
| 324 | TD=TD-459.6 |
| 325 | TF=TF-459.6 |
| 326 | TW=TW-459.6 |
| 327 | RETURN |
| 330 | END |

ISN

SOURCE STATEMENT

```

0 $IBFTC TEMP      NODECK
1      SUBROUTINE TEMP (TX,N )
C      ***** SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY *****
C      ***** NEW TEMPERATURE PROFILES ARE CALCULATED *****
2      COMMON/ONE/ CT(20),PC(20),w(20),DELTA(20),V1(20),VAP(20),A(16,6),
1AAOB(51),ZZ(51),BBMIX(51),DDELMX(51),HLIQ,HVAP
3      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
4      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
5      12 FORMAT (1X,16H*** ERROR 06 *** , 42H TEMP MORE THAN THIRTY TRIALS A
1RE REQUIRED )
6      K1=1
7      310 CALL KVAL (TX,N)
10     SUMY=0.
11     Q=0.
12     DO 300 I=1,NCP
13     CON1=VAP(I)*X(N,I)
14     IF(ABS(Y(N,I)-CON1).LE.1.0E-04) GO TO 301
17     Q=1.0
20     301 Y(N,I)=CON1
21     300 SUMY=SUMY+CON1
23     IF(ABS(SUMY-1.0).GT.1.0E-04) GO TO 303
26     IF(Q.LE.1.0E-04) GO TO 330
31     303 DO 302 I=1,NCP
32     302 Y(N,I)=Y(N,I)/SUMY
34     IF (K1.GT.30) GO TO 320
37     K1=K1+1
40     Q=TX*(1.0+(1.0-SUMY)/5.0)
41     IF(ABS(Q-TX).LT.30.0) GO TO 8
44     IF((SUMY-1.0).GE.0.) GO TO 7
47     TX=TX+30.0
50     GO TO 310
51     7 TX=TX-30.0
52     GO TO 310
53     8 TX=Q
54     GO TO 310
55     320 WRITE(6,12)
56     330 CONTINUE
57     RETURN
60     END

```


FORTRAN SOURCE LIST

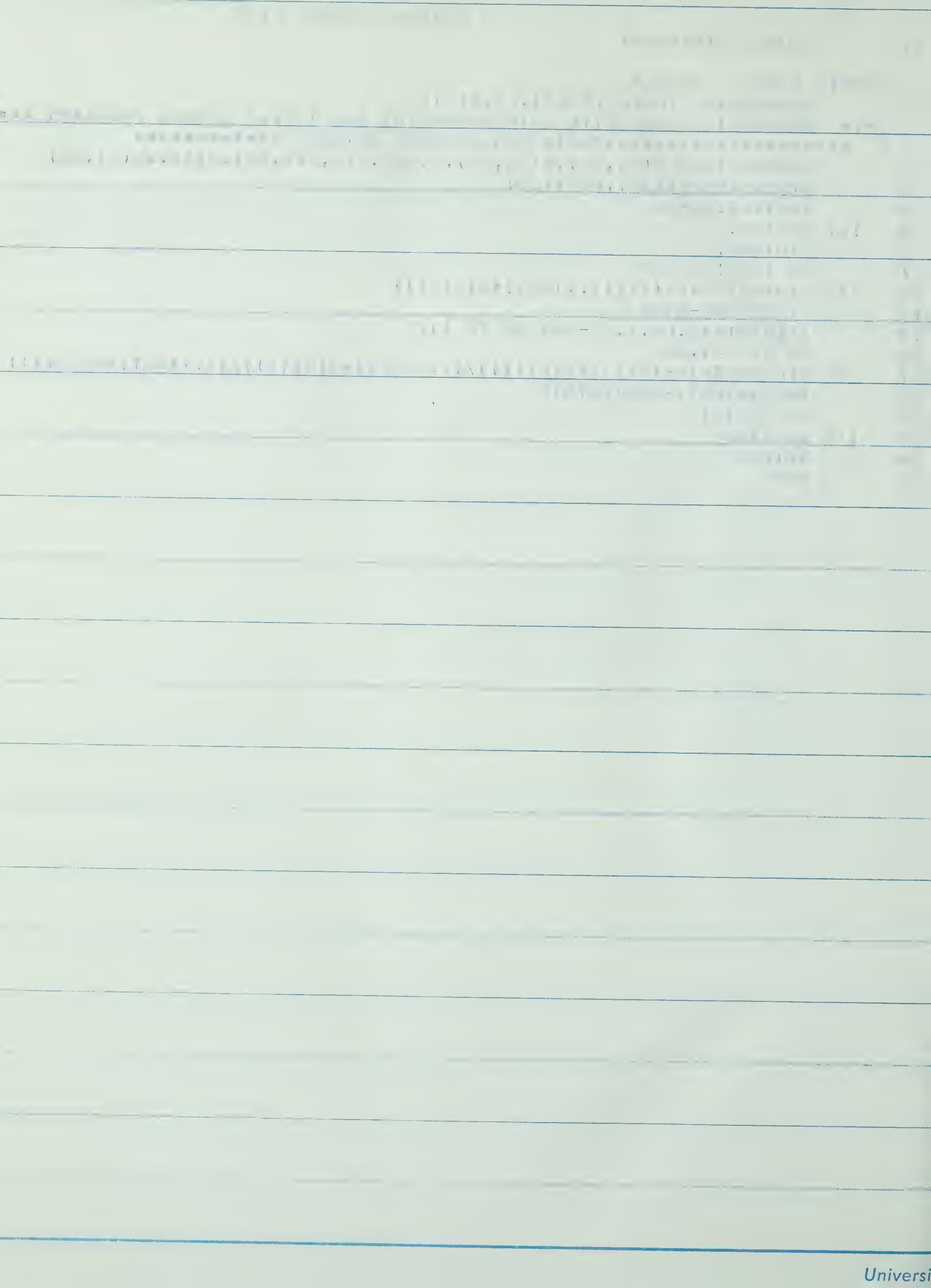
15N

SOURCE STATEMENT

```

0 $IBFTC THETA  NODECK
1      SUBROUTINE THETA (THET1,FX,BIDI)
C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
C  *****THETA CONVERGENCE METHOD *****
2      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3      DIMENSION FX(20),BIDI(20)
4      THET1=1.0E-10
5      111 GTHT=0.
6      GTHTP=0.
7      DO 110 I=1,NCP
10     110 GTHT=GTHT+FX(I)/(1.+THET1*BIDI(I))
12      GTHT=GTHT-DIST
13      IF(GTHT**2.LE.1.0E-08) GO TO 112
16      DO 92 I=1,NCP
17     92 GTHTP=GTHTP-(FX(I)*BIDI(I))/(1.+THET1*BIDI(I))/(1.+THET1*BIDI(I))
21      THET1=THET1-GTHT/GTHTP
22      GO TO 111
23     112 CONTINUE
24      RETURN
25      END

```



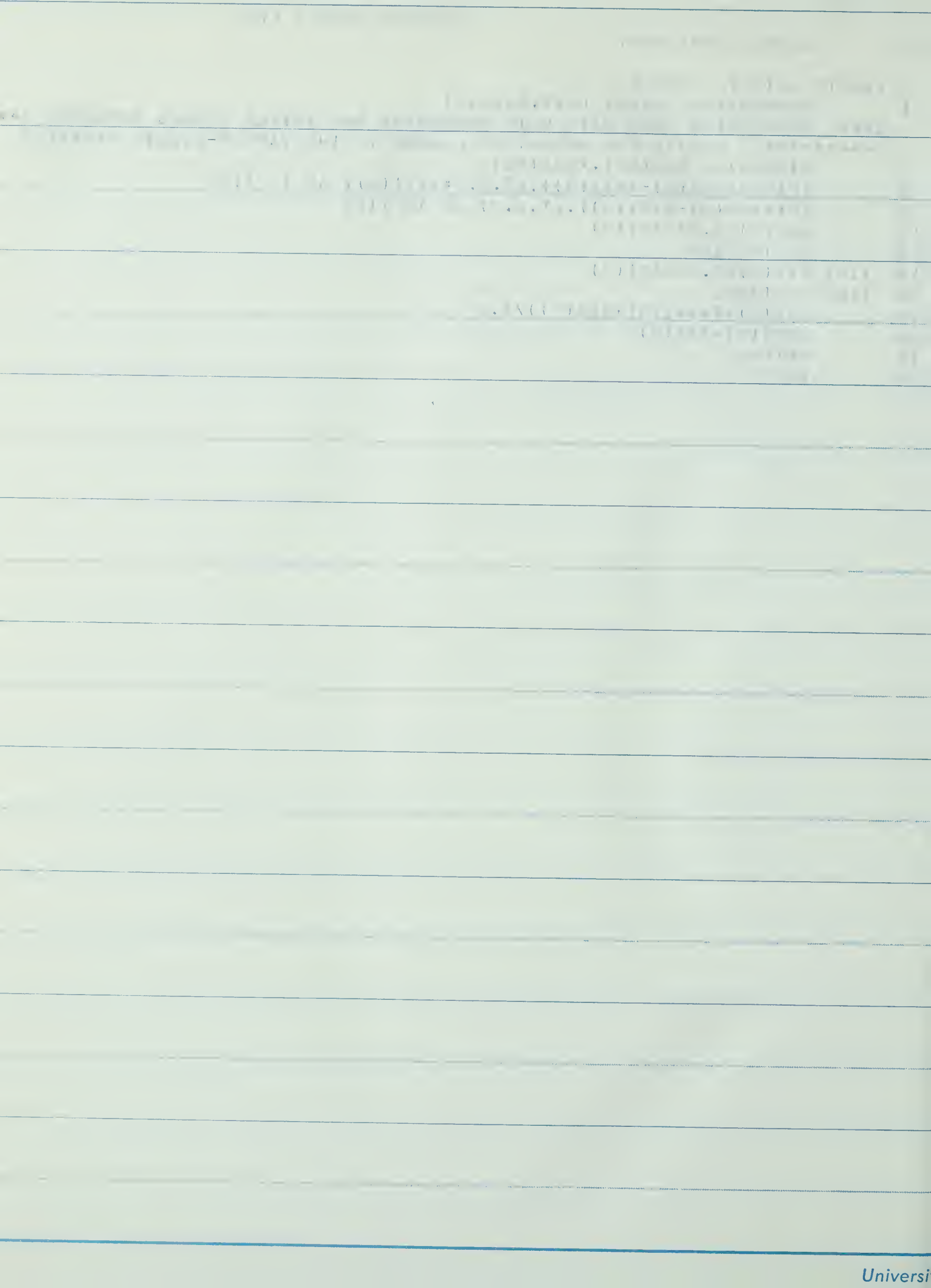
FORTRAN SOURCE LIST

ISN SOURCE STATEMENT

```

0  $IBFTC VLTEST  NODECK
1      SUBROUTINE VLTEST (XXX,XXX1,N)
   C***  SUBROUTINE USED WITH BOTH BERGAMINI AND THIELE GEDDES PROGRAMS ***
   C***** LIMITS THE AMOUNT OF CHANGE IN THE VAPOUR-LIQUID PROFILES
2      DIMENSION XXX(50),XXX1(50)
3      IF(ABS(XXX(N)-XXX1(N)).LT.0.2*XXX1(N)) GO TO 1100
6      IF((XXX(N)-XXX1(N)).LT.0.0) GO TO 1101
11     XXX(N)=1.2*XXX1(N)
12     GO TO 1100
13 1101 XXX(N)=0.8*XXX1(N)
14 1100 CONTINUE
15     XXX(N)=(XXX1(N)+XXX(N))/2.0
16     XXX1(N)=XXX(N)
17     RETURN
20     END

```

8
\$IBFTC VPLQP

SUBROUTINE VPLQP (DQC,DQR,SHDI,SHFI,AVP1,HDX,HDI)

C ***** SUBROUTINE USED WITH THIELE CEDDES PROCEEDURE ONLY *****

C ***** NEW VAPOUR-LIQUID PROFILES ARE CALCULATED *****

C ***** BOTTOM UP ENTHALPY BALANCES *****

COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AA(51,20)

COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)

COMMON/FOUR/ AVP(50),ALP(50),T(50)

COMMON/SIX/ SHV(50),SHL(50),ALIW(50,20),ADF(50,20),ASF(50,20)

DIMENSION AVP1(50)

GO TO (210,220),JXX

210 XXXX=SHDI

GO TO 230

220 XXXX=HDX

230 CONTINUE

AVP(NTP)=(BOT*(SHL(NTP)-SHL(NTP-1))-DQR)/(SHL(NTP-1)-SHV(NTP))

CALL VLTEST (AVP,AVP1,NTP)

M=NTP

MX=NTP-NFP-1

DO 73 N=1,MX

MK=M-N

NK=MK-1

JK=MK+1

AVP(MK)=(BOT*(SHL(MK)-SHL(NK))-(SHV(JK)-SHL(MK))*AVP(JK))/(SHL(NK)-SHV(MK))

CALL VLTEST (AVP,AVP1,MK)

73 ALP(MK)=AVP(JK)+BOT

ALP(NFP)=AVP(NFP+1)+BOT

ALP(NTP)=BOT

AVP(NFP)=(DIST*SHL(NFP-1)+BOT*SHL(NFP)-SHFI-(SHV(NFP+1)-SHL(NFP))*
1AVP(NFP+1))/(SHL(NFP-1)-SHV(NFP))

CALL VLTEST (AVP,AVP1,NFP)

M=NFP-2

DO 74 I=1,M

MM=NFP-I

NN=MM-1

AVP(MM)=(DIST*(SHL(NN)-SHL(MM))-(SHV(MM+1)-SHL(MM))*AVP(MM+1))/(S
1HL(NN)-SHV(MM))

CALL VLTEST (AVP,AVP1,MM)

74 ALP(MM)=AVP(MM+1)-DIST

AVP(1)=(DIST*(XXXX-SHL(1))-(SHV(2)-SHL(1))*AVP(2))/(XXXX-SHV(1))

CALL VLTEST (AVP,AVP1,1)

ALP(1)=AVP(2)-DIST

RETURN

END

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```

0 $IBFTC VPILPQ  NNODECK
1      SUBROUTINE VPLQP (DQC,DQR,SHDI,SHFI,AVP1,HDX,HDY)
C      *****SUBROUTINE USED WITH THIELE GEDDES PROCEEDURE ONLY*****
C      ***** NEW VAPOUR-LIQUID PROFILES ARE CALCULATED *****
C      ***** ENTHALPY BALLANCES FROM BOTH ENDS OF COLUMN *****
2      COMMON/TWO/ X(51,20),Y(51,20),P,NCP,NTP,NFP,BOT,DIST,AK(51,20)
3      COMMON/THREE/JX,JA1,JA2,JA3,JA4,JA5,JA6,JA7,JXX,FRAC,FRC,AA(4,20)
4      COMMON/FOUR/ AVP(50),ALP(50),T(50)
5      COMMON/FIVE/ REFEXR,      BXI(20),DXI(20),TD,TW,TF,FX(20)
6      COMMON/SIX/ SHV(50),SHL(50),ALIQ(50,20),ABF(50,20),ASF(50,20)
7      DIMENSION AVP1(50)
10     GO TO (210,220),JXX
11     210 XXXX=SHDI
12     GO TO 230
13     220 XXXX=HDY
14     230 ALP(NTP)=BOT
15     M=NTP
16     MM=NTP-NFP
17     DO 135 N=1,MM
20     MK=M-N
21     NK=MK+1
22     AVP(NK)=(BOT*(SHL(NTP)-SHL(MK))-DQR)/(SHL(MK)-SHV(NK))
23     CALL VLTEST (AVP,AVP1,NK)
24     ALP(MK)=AVP(NK)+BOT
25     135 CONTINUE
27     AVP(1)=REFEXR*DIST+DIST
30     MM=NFP-1
31     DO 136 N=1,MM
32     AVP(N+1)=(DIST *(XXXX-SHL(N))+DQC)/(SHV(N+1)-SHL(N))
33     CALL VLTEST (AVP,AVP1,N+1)
34     136 ALP(N)=AVP(N+1)-DIST
36     RETURN
37     END

```

Handwritten notes on lined paper, mostly illegible due to blurriness. The text appears to be a list or series of entries, possibly related to a course or project. Some legible fragments include:

- ... (1) ...
- ... (2) ...
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